Protection Coordination Study in Bhutan Transmission Network

Thesis for the Degree of Master of Science

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Göteborg, Sweden, 2010

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ABSTRACT

Since the effects of an unreliable power system transmission can be widespread and affect millions of people, as well as damage to life and equipment, therefore one of the most important requirements of protection system is to isolate and disconnect faulted parts of the system selectively and quickly. This purpose can be achieved by proper coordination of protective devices. One of the aims of this thesis was to make a general guideline from which proper coordination of transmission system protection can be developed in Bhutan network.

This thesis proposes a review of coordination of distance relays for transmission lines of a real network in Bhutan for study. The transmission network in Bhutan has under gone drastic change for past decade, due to growth of generation capacity with the target to generate 10,000MW by 2020 and target to achieve "Electricity for All by 2013". It has become very much necessary to study and analyze the protection system of existing transmission network.

This thesis also discusses the important of directional earth fault relay (67N) during the high impedance fault and its coordination. This thesis highlights the factor that effecting the operation of distance relay.

This study is carried out using Computer Aided Protection Engineering (CAPE) software by Electrocon International Incorporated, Michigan, USA.

Keywords: Coordination, CAPE software, Distance relays, Directional Erath fault, Power system, Protection system, Transmission network,

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Abbreviations

A	Ampere
ACSR	Aluminum Conductor Steel Reinforced
BPC	Bhutan Power Corporation Limited
BHP	Basochu Hydro Plant
CHP	Chukha Hydro Plant
CAPE	Computer Aided Protection Engineering
CB	Circuit Breaker
CT	Current Transformer
CTR	Current Transformer Ratio
DGPC	Druk Green Power Corporation
DL-G	Double phase to Ground
DoP	Department of Power
DPR	Detail Project Report
EF	Earth Fault
EHV	Extra High Voltage
GOI	Government of India
HV	High Voltage
IG	Inter Government
IDMT	Inverse Definite Minimum Time
JV	Joint Venture
kV	Kilo Volt
kVA	Kilo Volt Ampere
LV	Low Voltage
MVA	Mega Volt Ampere
MVAR	Mega Volt Ampere Reactive
MW	Mega Watt
NHPC	National Hydroelectric Power Corporation
NERC	North American Reliability Council
OC	Over Current
PMP	Power System Master Plan
P.u	Per unit
PT	Potential Transformer
PTR	Potential Transformer Ratio
SL-G	Single Phase to ground
SJVNL	Satluj Jal Vidyut Nigam Limited
THDC	Tehri Hydro Development Corporation Limited
THP	Tala Hydro Plant
VT	Voltage Transformer
WAPCOS	Water And Power Consultancy Services
67N	Directional Earth fault relay

CHAPTER 1

1. INTRODUCTION

1.1. Background and Motivation:

Transmission Network System in Bhutan is still in its infancy. As of now, it has two separate isolated grids called the Western and the Eastern grids. The Western grid comprises both 66 kV, 220 kV and 400kV transmission lines which are powered by the Basochu (64 MW), Chhukha (360MW) and the Tala (1020 MW) generation plants.

Currently, in the Eastern grid is powered by only the Kurichhu (60 MW) generation plant. The transmission voltage level of Eastern grid is 132 kV which is isolated from the Western grid. But somehow they are interconnected through Indian grid at different interface points to export any surplus electric energy to India. However, inter-connection of eastern and western grid and formation of national grid is in the process, due to upcoming hydro project namely Punatsangchu, Mangdechu, Dagachu, and etc. The construction of 220 kV interlinks between Tsirang and Jigmeling in Gelephu to connect the two grids is also under progress and schedule to complete by July 2011.[1]

With power demand growing rapidly at the rate of 8% per annum, Bhutan Power System Master Plan (PSMP) projected to increase the generating capacity and government committed to provide affordable and reliable electricity to all citizens by 2013 and committed to generate 10,000MW by 2020.[2] Due to which, power system network in Bhutan has been expanding rapidly for past few years, as a result the protection system setting/coordination were disturb and which may result abnormal tripping of the system.

Bhutan Power Corporation Limited (BPC), who is solely responsible for transmission of electric power in Bhutan. As of now BPC had no dedicate division who looks after the protection system study and also no software to carry out the study. Now BPC is high time to have dedicated units which will carry out the time to time protection coordination and system study in order to keep updating the protection system in network. The side benefits of coordination study the interrupting ratings of all protective equipment, conductors, and switches are checked for adequacy.

The objective of this thesis is to develop a standardized protection setting on Bhutan network and also maintain proper data base for the protection equipments. This will help to develop a maximum protection of equipment, transmission lines and a consistence statistical frame work for evaluating year-to-year variation of transmission service quality and stability performance indicators.

This thesis report is a small work based on the requirement, the power system analysis and protective device coordination for the safe and reliable power supply of the Bhutan network. In Bhutan, the generating stations are located at different parts of the country, which are interconnected by transmission networks and ultimately connected to Indian grid. In fact, this thesis work is not able to coordinate all protective devices for whole interconnected network, due to limited information from the Indian grid side and Generation Company. Therefore, this thesis report is a just starting and which is the beginning for the protection study on Bhutan network in future.

1.2. Objective of the thesis:

Power system network in Bhutan has been expanding rapidly for past few years and it is expected to further increase the network after completing the ongoing and upcoming transmission and hydro power projects, which is shown in table 3. With the rapid growth of transmission and distribution system, the power system is becoming more and more complex. Besides that, there is always small changes in loading conditions occur continuously in the power system. The power system must adjust to these changing conditions and continue to operate. Therefore, sometimes it has to upgrade the equipment and system protective devices. As the system becomes more complex, it is very important to carry out the detail power system studies and coordinate the protection system properly to maintain better system reliability. So far no coordination study is carried out after commission of the protective devices.

Therefore, the main goal of this thesis is to make general guidelines for protection coordination from which the transmission protection system will be improved in Bhutan. The main objectives are setting calculation, factors effecting the distance relay operations, recommendation for protection coordination proposal, coordination of existing systems, coordination curves, and justification of protective devices proposed for line such as earth fault protection (67N), tabulation of Coordination results and Analysis and recommendations.

1.3. Procedure and Outcome:

The load flow study and short circuit analysis has carried out with the help of CAPE Software and also with the DIgSLIENT. The result from the both software are same and it is attached in Appendix (B). For the protection relay coordination study is carried out only in CAPE, since CAPE software is the tools for protection engineering. While doing the simulation, the manufacturer’s guidelines also followed for distance relay settings [3] [4] [5]. The outcome of the thesis has tabulated and written in the form of report. Recommendations were made for the best protection of the grid network in Bhutan. A general report provided to improve the protection system as well as to review the coordination of the system by implementing this information.

1.4. Scope and Limitations:

- The power system model is built in CAPE with data available from Bhutan. The hydro projects under construction and the transmission line expansion being carried out at present is not considered in the proposed model.
- Due to insufficient data and time constraint, only 75% of network where able to study the distance relay coordination. In addition to that, transformer protection and Bus bar protection were also not taken into consideration for the study. The network that is selected for study is the network which has under gone many changes in the system for past years.
- Equivalent relay model has to used in some of the line since relay used were very old model and its model are not available in the CAPE.

1.5. Outline of the Thesis:

Chapter 1 describes the background and motivation for carrying out thesis and its objectives. It also describes the scope and limitation of the work.

Chapter 2 presents the existing network protection system, describes the problem definition of the existing protection system for which the coordination study needs to be done and also present the data that are required for this study. In this, present the overview of Power sector in Bhutan.

Chapter 3, describe the study aspects of the protection coordination studies and its objectives. It also high lights the factor affecting the performance of the relay operation and also describe the relay characteristics that are used in the existing network.

Chapter 4 discusses about methodology of the classical receipt for zone setting of the protection relay, coordination and same is verified by simulation. And also discuss the important of Directional earth fault relay (67N), definite time stage function and it is coordination.

Chapter 5 present the software used for the simulation and discussion of the simulation result. It also present the justifications of proposed settings and presenting the new setting table for distance relay and Directional earth fault relay.

Chapter 6, Conclusion and recommendations on the findings are made and suggestions for future studies on the work are proposed.

CHAPTER 2

2. DESCRIPTION OF NETWORK UNDER STUDY

2.1. Overview of Power Sector in Bhutan:

Power sector in Bhutan plays a vital role in small economy like Bhutan. Electricity is major contributor towards total revenue in the country. This chapter gives an overview of hydro power plants and Transmission & Distribution system in Bhutan. The Organizational Structure of the Bhutan Power Sector is presented in figure (1).

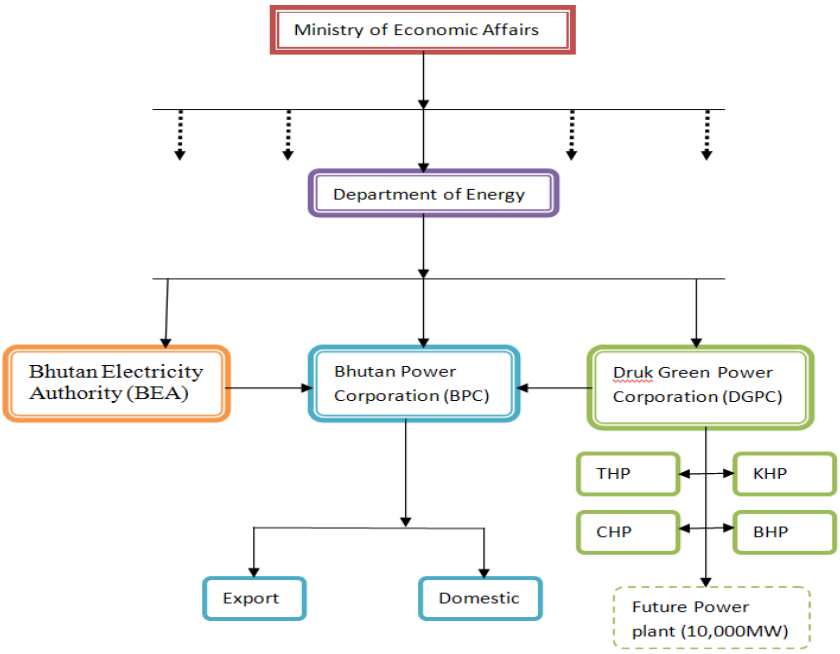


Figure 1: Organizational structure of Bhutan Power Sector

Prior to July 2002, all electricity transmission and distribution encompassing the development and construction of Mini and Micro Hydropower Plants in Bhutan was catered by the Department of Power (DoP) under the Ministry of Trade and Industry. From July 2002, the erstwhile Department of Power under the Ministry of Trade and Industry was bifurcated into three separate entities namely Bhutan Power Corporation Limited (BPC)– a public utility, Department of Energy – A government department responsible for policy, planning and coordination activities for the energy sector and Bhutan Electricity Authority – Regulatory body under the Department of Energy. It can be seen from figure 1 that, BPC is the soul entity that purchases power from different generation station and sale it to its domestic customer and as well as export to India. BPC has mandate to provide electricity to all by 2013. At present, the transmission network covers 13 Dzongkhags with about 822.86 km of line length (66, 132, 220 & 400kV) and 22 substations (619.5MVA). The transmission grid of Bhutan consists of Western Grid and Eastern Grid which are yet to be interconnected. However, interconnection work are under progress and by end of year 2011 Bhutan will have one national grid. Detail of these lines is shown in table 1.

Table 1: Transmission line length

Sl.No.	Particulars	Line length (km)	Remarks
1	400 kV Line	74	
2	220 kV (Double Circuit)	71.28	
3	220 kV (Single Circuit)	126.62	
4	132 kV	304.29	
5	66 kV	246.67	
	Total	**822.86**	

Source [1]

From 1st January 2008, all the generating stations are merged under single entity called 'Druk Green Power Corporation', which will be a government owned body, responsible for hydropower generation in the kingdom. The total installed capacity of DGPC currently stands at 1480MW. The detail installed capacity of hydro power plant is shown in the table 2. DGPC has mandate to increase the installed capacity to 10,000MW by 2020. In line with this, the Royal Government, has approved the following ten (10) hydroelectric projects in its 14th session of the Lhengye Zhungtshog held on 14th August 2008 are shown table3 below.[2]

Table 2: Existing installed capacity power

Sl. No.	Name of Hydro Power Plant	Installed capacity in MW	Remarks
1	Chhukha	336	
2	Basochu (Upper & Lower)	64	
3	Kurichu	60	
4	Tala	1020	
5	Mini/Micro	8.062	Under BPC
	Total	**1488.062**	

Source [6]

Table 3: Status of future Hydropower development in Bhutan

Sl No	Project	Capacity (MW)	DPR Schedule	Indian PSU identified for DPR	Construction Schedule	Funding Model
1	Dagachu	114	Under construction			
2	Punatsangchu-I	1200	Done	Completed	2008-2015	IG
3	Punatsangchu-II	1000	2006-2008	WAPCOS	2009-2016	IG
4	Mangdechu	720	2006-2008	NHPC	2009-2017	IG
5	Sunkosh Storage(Main Dam)	4000	2009-2011	NHPC	2011-2020	IG
6	Kuri Gongri	1800	2009-2011	NHPC	2012-2019	IG
7	Amochu Storage	620	2009-2011	NTPC	2012-2018	IG
8	Wangchuk Storage	900	2009	NTPC	2010-2017	JV
9	Bunakha Storage	180	2009	SJVNL	2010-2016	JV
10	Kholongchu	486	2009-2010	THDC	2011-2017	JV
11	Chamkharchu-I	670	2009-2010	SJVNL	2011-2017	JV
	Total	**11,690**	By 2020 10,000MW			

Source [2] [6]

Note: Inter-Govt. (IG) - project will be between GOI & RGOB with 40% grant and 60% Loan from GOI. Joint venture (JV) - Public sector from Bhutan and India will participate.

2.2. Problem Definition:

In Bhutan, the transmission grid voltage levels are 400kV, 220kV, 132kV and 66kV. The single line diagram of the network is shown in appendix (A).The transmission lines are overhead lines with ACSR conductors and are supported on steel tower. All power transformers and equipment are out door type. The system mainly protected with distance relay, directional earth fault relay, over current relay, circuit breakers, etc.

With such a network, the problem is how to maintain a safe, reliable and efficient energy supply by ensuring that transmission line and equipment are well protected in the event of fault. Protection system must recognize the existence of a fault and initiate circuit breaker operation to disconnect faulted line of the system selectively and quickly. The actions required assure minimum disruption of electrical services and limit damage in the faulted equipment. This can only be achieved if the protective devices are well coordinated. Although, the existing network was coordinated when it was installing but it should be reviewed of coordination as causes described in chapter 1. The equipment has been upgraded in the network due to growing demand of power where in most cases it was not planned with protective device coordination in mind. Therefore, there is loss of selectivity between upstream and downstream protective devices. In this circumstance, this study needs to be done for proper coordination.

Another problem is that, most of the directional earth fault relay functions are disable. It is very important to enable this function. During the high impedance fault the distance relay will not detect the fault, so in that case the direction earth fault will sense the fault and cleared the fault. The detail simulation reports are discussed in the Chapter 4.

2.3. System Data:

The system data used to build the network are taking from the data base available with the BPC and DGPC. Power plants under considered for the study are shown in table 2. The positive and zero sequence impedance of the conductors are very necessary for the distance protection setting of transmission lines. The impedances of conductor which used in the existing network are given in table 4. Type of relay used in the network and CT & PT ratios are given in table 5.

Table 4 : Transmission line data considered for study.

Sl.No	Description	Conductor parameter			
1	Conductor type	Twin Moose	Zebra	Panther	Dog
2	Voltage level (KV)	400	220	132	66
3	Positive sequence R (ohms/km)	0.0264	0.07	0.1695	0.217
4	Positive sequence X (ohms/km/)	0.309	0.4063	0.4298	0.417
5	Zero sequence R (ohms/km)	0.263	0.187	0.4227	0.99
6	Zero sequence X (ohms/km)	1.1325	1.087	1.35	2.27
7	Nominal Rating (MVA)	924.22	224.82	90.31	27.32

Source [1]

Table 5: Protections and CT & PT ratios considered in study

Sl. No	Element Nme		Type of Protection Relay		CT Ratio(A)		PT Ratio (kV/V)
	From	To	From	To	From	To	
1	KHP	Nangkhor	SPHM 101	EPAC3000	500/1	300/1	132/110
2	Nagkhor	Nanglam	EPAC300	EPAC300	300/1	300/1	132/110
3	Nanglam	Tingtibi	EPAC300	EPAC300	300/1	300/1	132/110
4	Tingtibi	Gelephu	EPAC300	EPAC300	300/1	300/1	132/110
5	Gelephu	Salakati	SPHM 101	******	300/1	*****	132/110
6	Chukha	Chumdo	7SA6xxx	REL511	300/1	300/1	66/110
7	Chumdo	Jemina	REL511	PD532	300/1	200/1	66/110
8	Jemina	Olakha	PD532	7SA6xxx	200/1	600/1	66/110
9	Olakha	Semtokha	7SA6xxx	REL511	600/1	300/1	66/110
10	Semtokha	Lobeysa	REL511	REL511	300/1	300/1	66/110
11	Lobeysa	Rurichu	REL511	REL511	300/1	400/1	66/110
12	Rurichu	Basochu	REL511	REL511	400/1	400/1	66/110
13	Rurichu	Semtokha	REL511	REL511	300/1	300/1	220/110
14	Semtokha	Chukha	REL511	REL511	300/1	600/1	220/110
15	Chukha	Malbesa	REL511	REL511	600/1	800/1	220/110
16	Malbesa	Birpara	REL511	*****	800/1	*****	220/110
17	Chukha	Birpara	REL511	*****	800/1	*****	220/110
18	Tala	Malbesa	7SA6xxx	REL512	2000/1	1000/1	400/110
19	Tala	Binaguri	7SA6xxx	*****	2000/1	*****	400/110
20	Malbesa	Binaguri	REL512	*****	1000/1	*****	400/110

Note: ***** *Data not available, since the substation is under Indian grid.*

Above are the lists of the line that we have considered for the study of relay coordination. Details simulations were discuss and presented in chapter 4 and 5.

2.4. Existing Protection System:

As describe in the Chapter 1, transmission network of Bhutan is divided into two, i.e Western and Eastern grid and ultimately connected with Indian grid. For my study, the networks are divided into three parts. They are 132kV system in Eastern grid and western grid into two parts, 220kV and 66kV system. The details networks are show in the figure below:

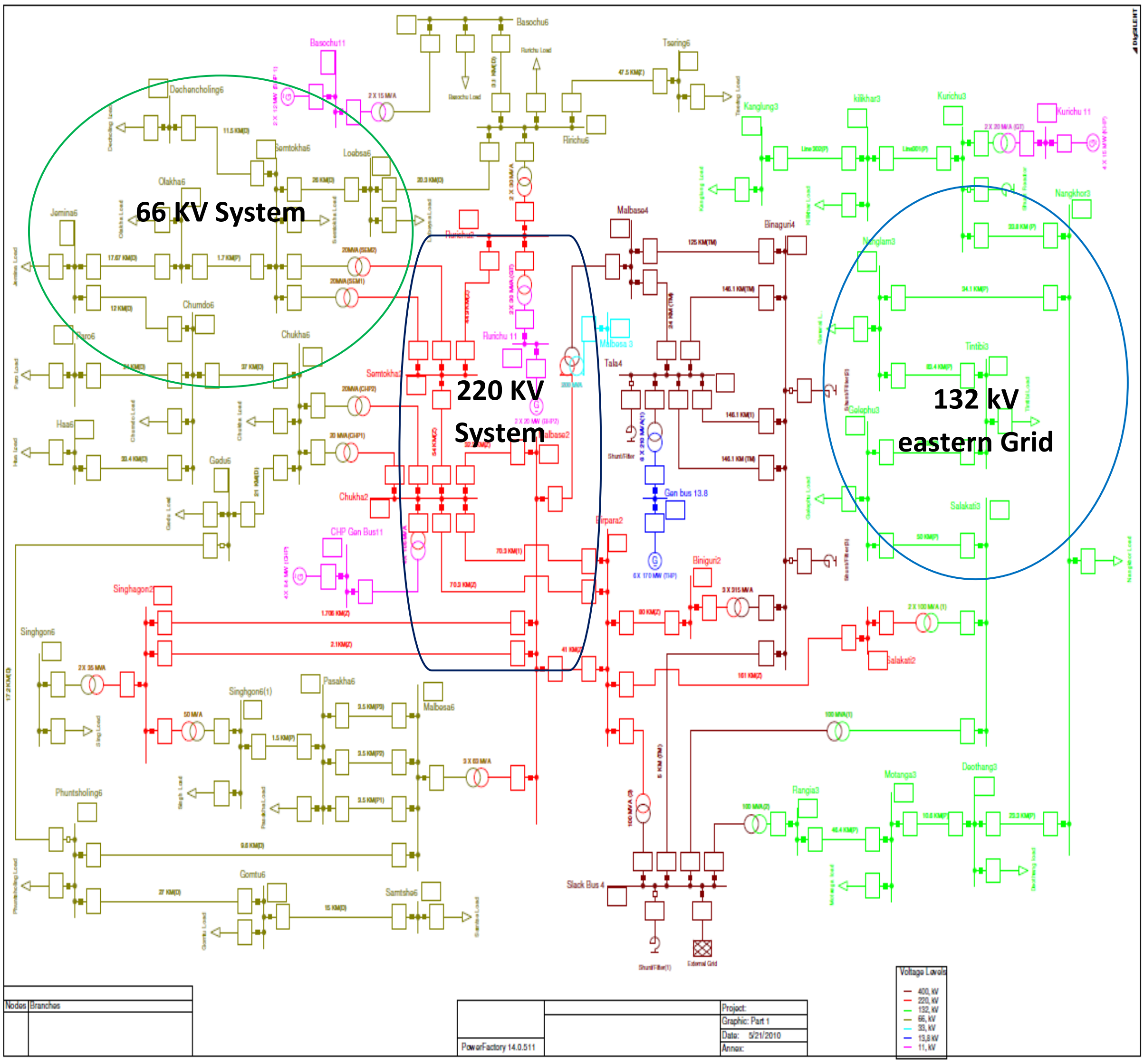


Figure 2: Network showing which is considered for study

Norms of protection system followed in Bhutan are shown in table below: The scheme used is Non-switched scheme for all transmission line

Table 6: Protection scheme used in Transmission line:

Sl.No	Votage level	Protection Scheme	Remarks
1	400 kV Line	Main-I Numerical Distance Scheme Main-II Numerical Distance Scheme	Main-II, same manufacture but with different model.
2	220 kV Line	Main-I Numerical Distance Scheme Main-II Numerical Distance Scheme	Main-II, same manufacture but with different model
3	132 kV Line	Main-I Numerical Distance Scheme Backup Protection: 3 Nos dir. IDMT OC relays and 1 No. dir. EF relay.	Backup protection is of Electromechanical relay.
4	66 kV Line	Main-I Numerical Distance Scheme Backup Protection: 3 Nos dir. IDMT OC relays and 1 No. dir. EF relay.	Backup protection is of Electromechanical relay

The distance relays used are of numerical, which is of five stepped distance protection zone, with zone 1, 2&3 in forward direction and Zone 4 as reverse direction, Zone 5 is not used. The Classical method is used for Zone setting of the existing distance relay. Figure 3 below shows set up with the following criteria:

- ✓ Zone 1: Forward direction, 80% of the line length with instantaneous trip.
- ✓ Zone 2: Forward direction, 100% of the protective line length, plus at least 20% of the shortest adjacent line and with time delay of 0.4 sec.
- ✓ Zone 3: Forward direction, 100% of the protective line length, plus 100% of adjacent line, plus 20% of the third line and with time delay of 0.8 sec.
- ✓ Zone 4: Reverse direction, 10% of the protective line length, with time delay of 1 sec.

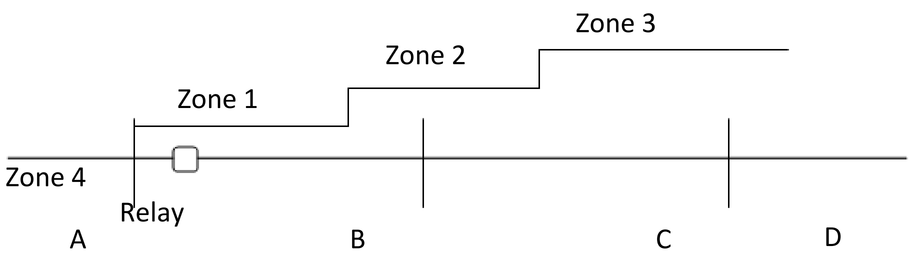


Figure3: Distance relay protection zones

While going through the setting for different lines, it was found that some zone settings are under reach and some are over reach. This is checked and simulated with the help of CAPE software. The details simulation is discuss in chapter 4 and 5. And also it was found that Directional earth fault function is not used as backup protection. It is very important to used, since the distance protection will not detect the high impedance fault.
There are two type of scheme in distance protection system are:

- ✓ **Non-switched scheme**: This scheme is faster and more accurate but is costly. There are 6 starters, 3 for phase faults and 3 for ground faults. There will be independent measuring units for both phase faults and earth fault for each phase, for all three zones, totaling to 18 units.
- ✓ **Switched scheme**: This scheme is relatively slow in operation and the risk of total scheme failure in the event of failure of the only one measuring unit available. In this scheme only one measuring unit will be used for all types of faults. This single measuring unit is switched to the correct fault loop impedance by switching-in the respective voltages and currents by the starter.

CHAPTER 3

3. STUDY ASPECT FOR PROTECTION COORDINATION STUDIES

3.1.Protective Objective:

The objective of the protection is to quickly isolate section from both ends so that the rest of the system can function satisfactorily. More fundamental, however, is that the power system should operate in a safe manner at all the times. But no matter how well designed, faults will always occur on a power system and these faults may represent a risk to life or property. The main four functional requirements of the relays are: [7]

- ✓ Reliability
- ✓ Selectivity
- ✓ Sensitivity
- ✓ Speed

Reliability:
The most important requisite of protective relay is reliability since they supervise the circuit for a long time before a fault occurs, if a fault then occurs, the relays must respond instantly and correctly. When protective relays fails to function properly, the allied mitigation features are largely ineffective. Therefore, it is essential that protective-relaying equipment be inherently reliable, and that its application, installation, and maintenance be such as to assure that its maximum capabilities will be realized.

Selectivity:
The relay must be able to discriminate (select) between those conditions for which prompt operation is required and those for which no operation, or time delayed operation is required. The property of selectivity tripping is also called ‘discrimination’ and is achieved by two general methods.

- ✓ Time Grading
- ✓ Unit system

Sensitivity:
The relaying equipment must be sufficiently sensitive so that it operates reliably when required under the actual conditions that produces least operating tendency. This is a term frequently used when referring to the minimum operating level (current, voltage, power etc.) of relays or complete protection scheme. The relay or scheme is said to be sensitive, if the parameters of the primary operating setting is low.

Speed:
The function of protection systems is to isolate faults on the power system as rapidly as possible. Therefore, the relay must operate at the required speed. It should neither be too slow which may result in damage to the equipment nor should it be too fast which may result in undesired operation.

3.2. Relay Characteristics:

The distance relays need to have a characteristic that will ensure correct operation when a short circuit fault occurs within the zone of protection and at the same time avoid miss-operation under no-fault conditions. The protected transmission line is in the impedance plane with the area of arc resistance that has to be covered by the protection element.

Some of the numerical relays measure the absolute fault impedance and then determine whether operation is required according to impedance boundaries defined on the R/X diagram. Whereas, in traditional distance relays they compare the measure voltage with a replica voltage derived from the fault current and the zone impedance setting to determine whether the fault is within zone or out-of-zone. The common types compare either the relative amplitude or phase of two input quantities to obtain operating characteristics that are either straight lines or circles when plotted on an R/X diagram.

3.3. Types of Distance relay:

The conventional distance relay uses three distance measuring units. Distance relays can be classified into phase relay and ground relays. Phase relays are used to protect the transmission line against phase fault (3phase, L-L) and the ground relays are used to protect against ground faults (SL-G, DL-G). The most important and versatile family of relays is the distance relay group. It includes the following major types-

- ✓ Impedance relays
- ✓ Reactance relays
- ✓ MHO relays
- ✓ Angle impedance relays
- ✓ Quadrilateral relays etc.

At present distance relay used in Bhutan network are mostly of ABB make and few of AREVA and SIEMENS make. The relay characteristics used in the Bhutan network are of Quadrilateral and MHO. Therefore, the characteristics of MHO relay and Quadrilateral relay are discussed only in this study.

3.3.1. Quadrilaterals relay Characteristics.

A quadrilateral relay is suitable for long lines and as well as for short lines. This relay characteristics would allow the ground fault resistive reach to be increased or decreased independently of the forward reach and source impedance behind relay so that the required ground fault resistive coverage can be achieved. It is therefore provides better resistive coverage than any mho-type characteristic for short lines. To avoid excessive errors in the zone reach accuracy, it is common to impose a maximum resistive reach in terms of the zone impedance reach. Obviously, the characteristic needs to have a shape and be wide enough to provide this coverage. At the same time the characteristic should have a shape and be narrow enough so that the dynamically changing load impedance does not enter inside the characteristic, which will result in undesired tripping of the protected line at the time fault. The characteristics are shown in the figure below:

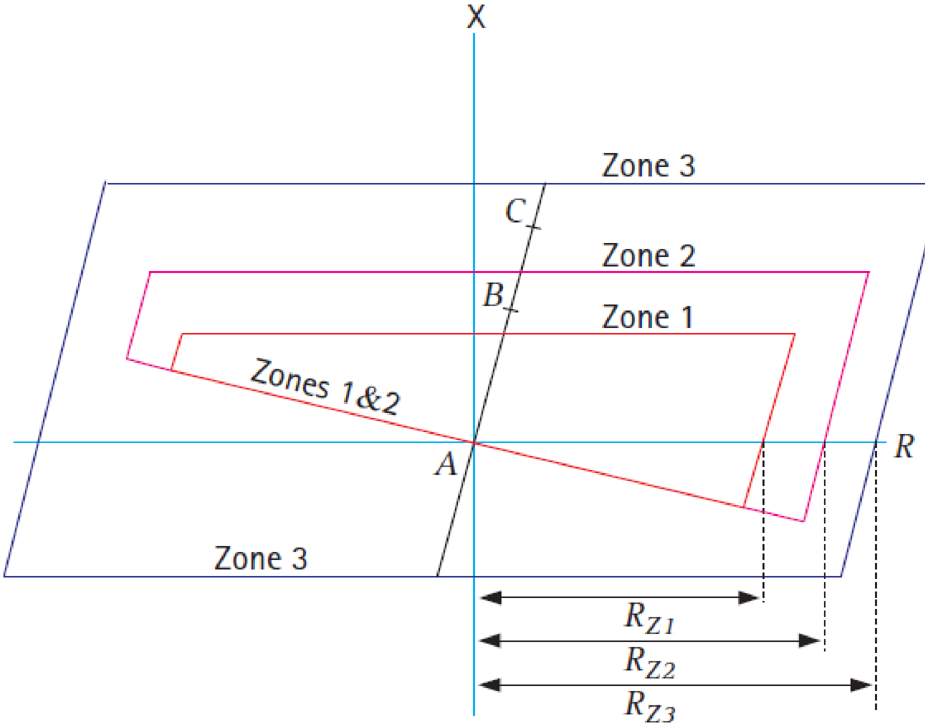


Figure 4: Distance relay Characteristics [7]

3.3.2. MHO Characteristics:

The MHO characteristic, as seen on the impedance polar diagram, is a circle whose diameter is the relay impedance setting vector, such that the characteristic passes through the origin of the impedance diagram, as shown in Figure 5. This demonstrates that the impedance element is inherently directional and such that it will operate only for faults in the forward direction along the protective line. Therefore MHO relay is directional. In this impedance reach varies with fault angle. As the line to be protected is made up of resistance and inductance, its fault angle will be dependent upon the relative values of R and X at the system operating frequency. Therefore, Relay Characteristic Angle (RCA) **φ** is set less than the line angle, so that it is possible to accept a small amount of fault resistance without causing under-reach.

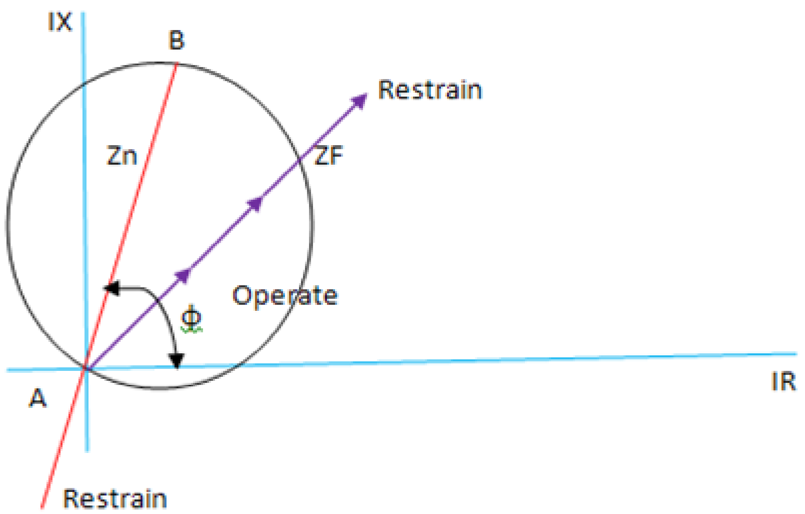


Figure 5: Mho impedance characteristic

3.4. System Impedance:

The impedance of the power system is divided into two parts. Firstly, the impedance behind the relaying point, including the generators, feeders, transformers, etc., forms the source impedance. The second part is the impedance to the fault in front of the relaying point, which is governed by the geometrical arrangement, size, shape, spacing and material of the conductors. Generally, this impedance data are provided by manufacturers. Both of this impedance must be known to determine the faults levels and setting of the relays. However, all the setting calculations are in terms of secondary impedance. Therefore, the relation between secondary and primary are presented below:

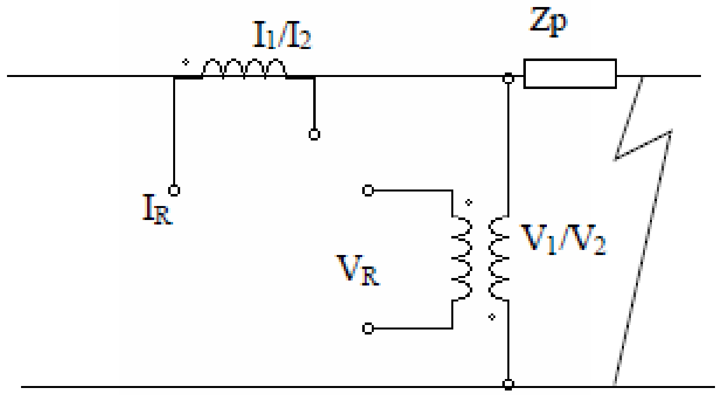


Figure 6: Impedance measured by distance relay

$$Z_R = \frac{V_R}{I_R} = \frac{V_{FP} \times \frac{V_2}{V_1}}{I_{FP} \times \frac{I_2}{I_1}}$$

$$Z_R = \frac{V_{FP}}{I_{FP}} \times \frac{\frac{I_1}{I_2}}{\frac{V_1}{V_2}} = Z_P \times \frac{C.T.ratio}{V.T.Ratio} = \textbf{Secondary impedance } (\mathbf{Z_S})$$

Where, Z_R is the relay impedance, V_{FP} is the fault voltage at the fault point, I_{FP} is the fault current at the fault point, Z_p is the positive sequence impedance of the line on primary side and Z_S is the secondary positive sequence impedance of the line on secondary side.

3.5. Coordination Study:

The basic role of the protection scheme is to sense faults and isolate these faults by opening all incoming current paths. However, the protection scheme must be selective so that only faulted element is removed i.e. isolated. Therefore, a coordination study maximizes power system selectivity by isolating faults to the nearest protective device, as well as helping to avoid mal-operations. The other upstream devices must be designed to operate in sequence to provide back-up protection, if any device fails to respond, this is called selective coordination. One of the main topics of concern protection engineers is the proper coordination behavior of different relay units so as to avoid relay mal-operation. In fact, for proper coordination, it is better to follow the relay manual guides which are provided by manufacturers. A new or revised coordination study should be made when the available short-circuit current from the power supply is increased; when new large loads are added or existing equipment is replaced with larger equipment; or when protective devices are upgraded. Typical three zone time-distance characteristics of distance relay is shown in sketch below figure 7.

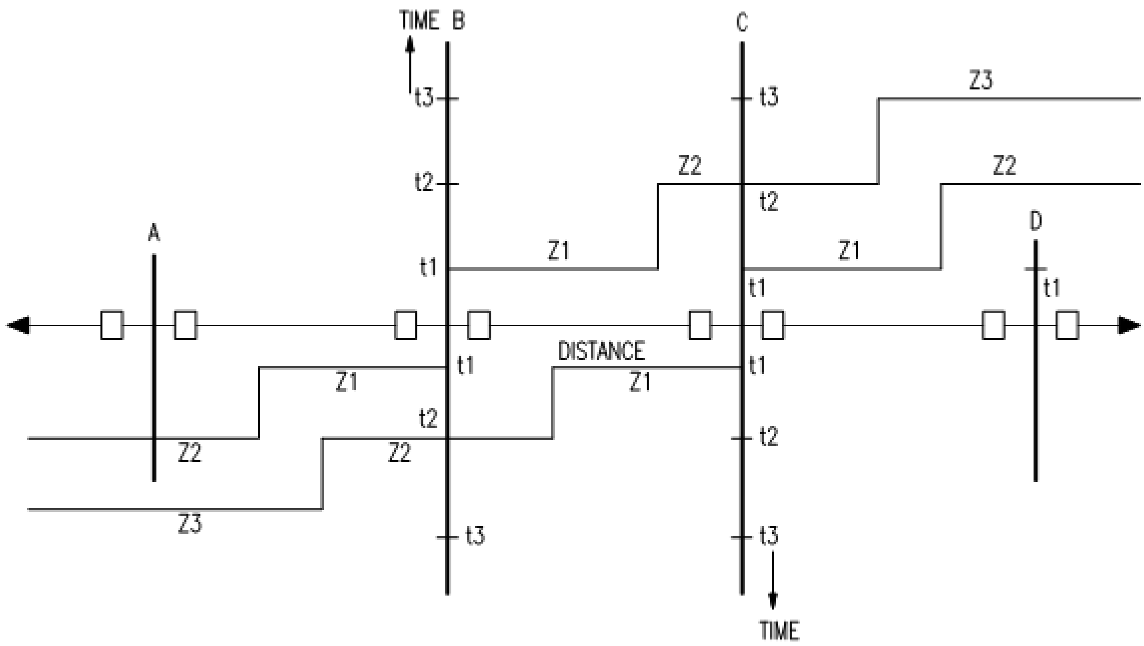


Figure 7: Three Zone time-distance Characteristics

3.6. Primary and back-up Protection:

A power system is divided into various zones for its protection. There is a suitable protective scheme for each zone; it is the duty of the primary relays of that zone to isolate the faulty element. The primary protection is the first line to defense. If the primary protection fails to operate, there is a back-up protective scheme to clear the fault as a second line to defense.

The causes of failures of primary protection could be due to failure of the CT/VT or relay, or failure of the circuit breaker. The back-up protection should also preferably be located at a place different from where the primary protection is located. Further, the back-up protection must wait for the primary protection to operate, before using the trip command to its associated circuit breakers. In other words, the operating time of the back-up protection must be delayed by an appropriate amount over that of the primary protection. Thus the operating time of the backup protection should be equal to the operating time of primary protection plus the operating time of the primary circuit breaker. In general, there are three types of back-up Protection scheme in power system protection: [7]

- ✓ Local back-up protection
- ✓ Breaker back-up protection
- ✓ Remote back-up protection

Local back-up protection:

This is kind of a local back-up in which an additional relay is provided for back-up protection. This is achieved by protection which detect an un-cleared primary system fault at its own location and which then trip its own circuit breakers, shown in figure 8 below:

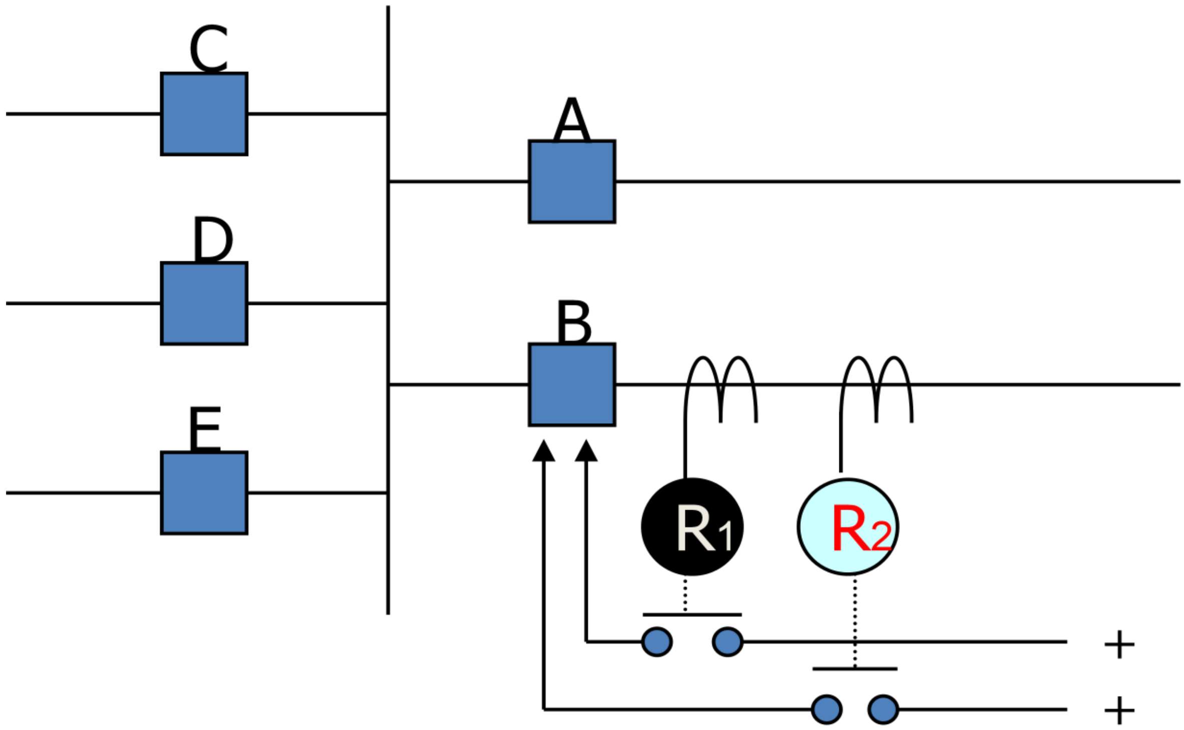


Figure 8: Local back-up protection

Breaker back-up protection:

This is also kind of a local back- up is necessary for a bus bar system where a number of circuit breakers are connected to it. When a protective relay operates in response to a fault but the circuit breaker fails to trip, the fault is treated as a bus bar fault. In such a situation, it becomes necessary that all other circuit breakers on that bus bar should trip. Figure 9 below shows tripping logic circuit of Breaker back-up protection.

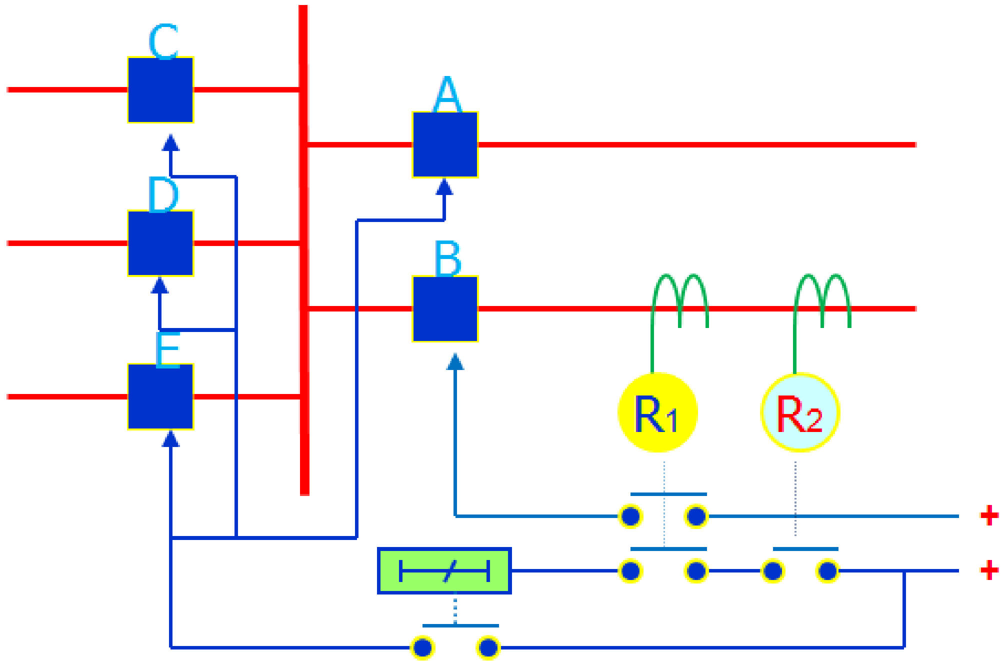


Figure 9: Tripping logic circuit of breaker back-up protection.

Remote back-up Protection:
When back-up relays are located at a neighboring station, they backup the entire primary protective scheme which includes the relay, circuit breaker, PT, CT and other elements. This is provided by protection that detects an un-cleared primary system fault at a remote location and then issue a local trip command e.g. the second or third zones of distance relay. It is the cheapest and simplest form of back-up protection and is widely used back-up protection for transmission line.

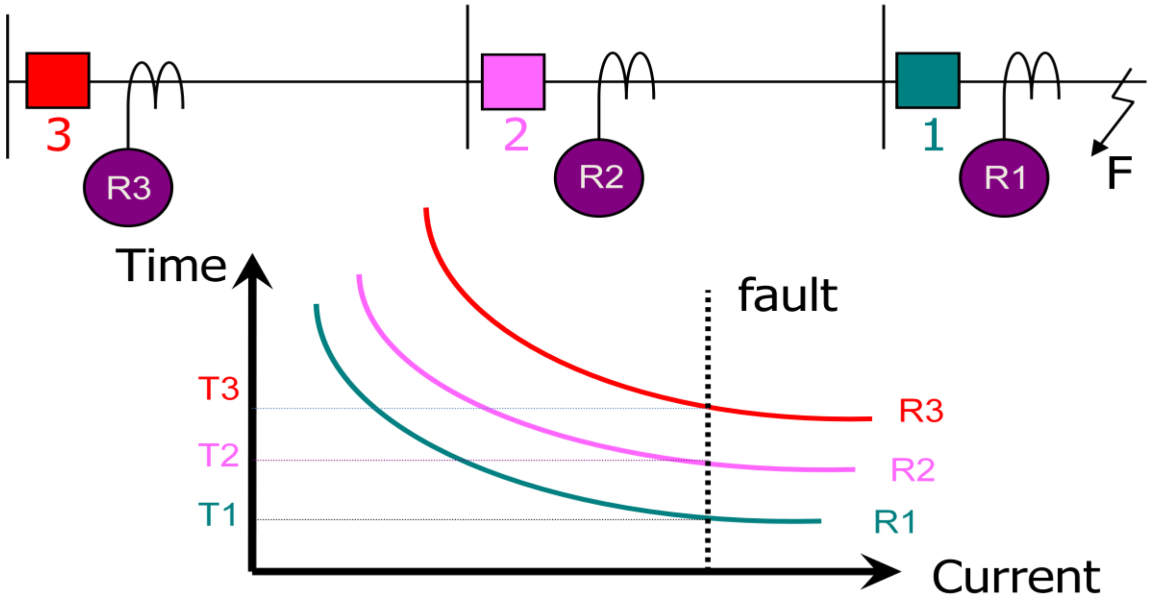


Figure 10: Remote back-up protection

3.7. Factors Affecting Distance Relay Operation:

Proper settings of protective relays are essential for the reliable operation of electrical power systems, during both fault and normal system operating conditions. The setting of distance relays should ensure that they are not going to operate when not required (security) and will operate to trip when necessary (dependability). The ideal relay operating characteristics can also be influenced by parasitic phenomena, such as CT saturation. The main factors that affecting the operation of distance relay are discuss as below:

3.7.1. Fault Resistance:

Ground resistance and Arc resistance are the two components of the fault resistance. If a flashover from phase to phase or phase to ground occurs, an arc resistance is introduced into the fault path which is appreciable at higher voltages. The arc resistance is added to the impedance of the line and hence, the resultant impedance which is seen by distance relays is increased. In case of ground faults, the earth resistance is also introduced into the fault path. The arc resistance is treated as pure resistance in series with the line impedance, where reactive component is negligible. The arc resistance has little effect on accuracy of zone-1 unit as it operates instantaneously before the arc can stretch appreciably length. Therefore, arc resistance will have greater impact on accuracy of backup zones (time delayed) as the arc stretches appreciably.
Figure 11 shows the effect of fault resistance on distance relay impedance reach. For a fault at the point F, the actual line impedance up to fault is **Zf** but due to the presence of the fault resistance, the impedance measured by the relay is **(Zf + R).** That is why, this shows that arc resistance causes under-reach and relay fails to operate.

Due to the physical nature of an arc, there is a non-linear relationship between arc voltage and arc current, which result in a non-linear resistance. Using the empirical formula derived by A.R Van C. Warrington, [9] the approximate value of arc resistance can be assessed as:

$$R_a = \frac{28710}{I^{1.4}} \times L$$

Where: R_a = Arc resistance in ohms
L = Length of arc in meters
I = Arc current in A

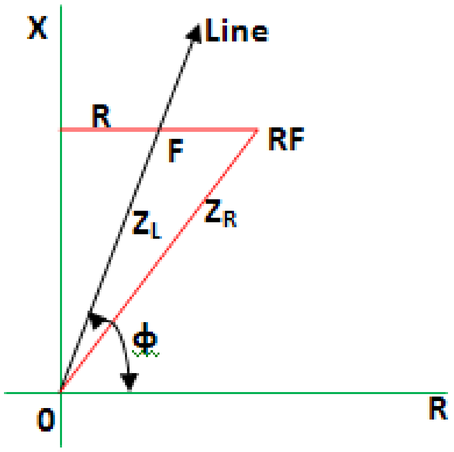


Figure 11: Effect of fault Resistance.

3.7.2. Infeed Effect:

The effect of intermediate current source between relay location and fault point is termed as infeed effect. This will cause a distance relay to under reach. Distance relay is said to under reach when the impedance presented to it is apparently greater than the impedance to the fault. Consider the sketch indicated in figure 12. A fault at **F** on the line **BC** is at a distance of **Z1+Z2** for the relay at station **A**. But when current **I2** flows from bus **D**, the impedance to the fault as seen by the relay at **A** is:

$$Z_1 + \frac{I_1+I_2}{I_1} \times X \times Z_2$$

So for relay balance:

$$Z_1 + Z_2 = Z_1 + \frac{(I_1+I_2)}{I_1} \times X \times Z_2$$

Therefore the effective reach is

$$Z_1 + \left(\frac{I_1}{I_1+I_2}\right) Z_2$$

Thus the fault is seen by the relay A as farther than what it really is, it is clear from above equations that relay will under reach due to the infeed effect. The effect of infeed becomes more pronounced with more interconnections at station B.[9]

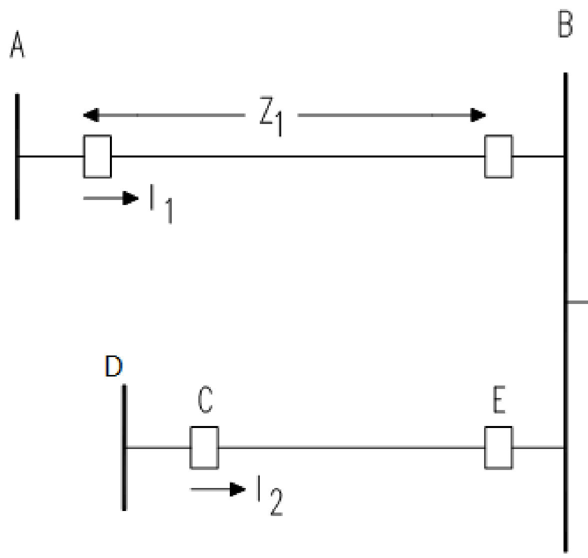


Figure 12: Infeed effect on distance relays.

3.7.3. Branching-off effect:

This effect will cause distance relay to over reach. It is said over reach, when the apparent impedance presented to it is less than the impedance to the fault. In the figure 13, a fault at **F** is at the distance of $\mathbf{Z_1+Z_2}$ for the relay at station **A**. But when current $\mathbf{I_1}$ gets distributed as $\mathbf{I_2}$ & $\mathbf{I_3}$ at station **B**, the impedance to fault seen by the relay at station **A** will be $\mathbf{(Z_1 + I_3/I_1 * Z_2)}$ which is less than $\mathbf{(Z_1+Z_2)}$.
Then the fault is seen by the relay as nearer than what it really is i.e. distance relay overreaches due to branching-off effect. This overreaching tendency will cause the relay to lose its selectivity.

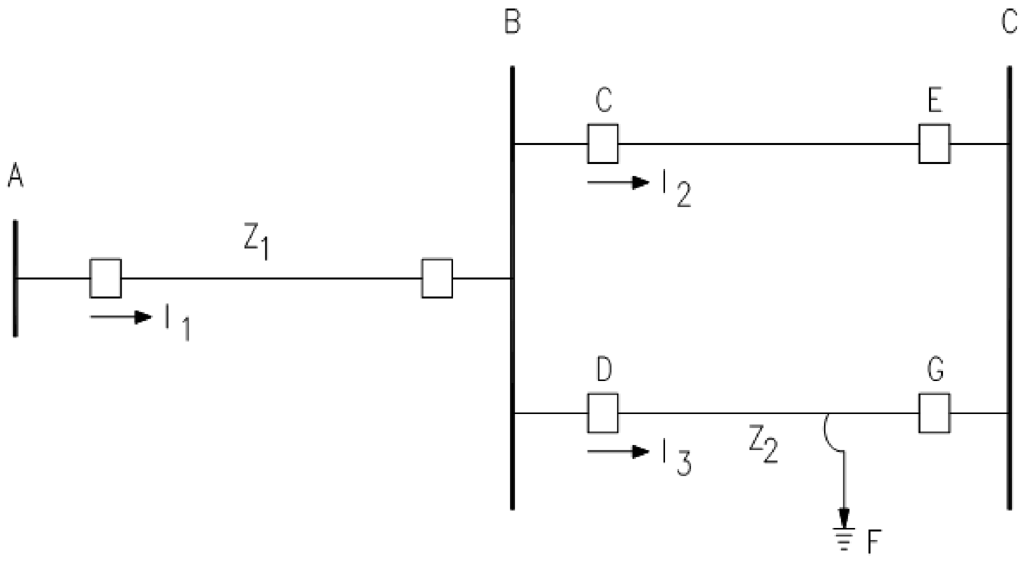


Figure 13: Branching-off effect.

3.7.4. Load Encroachment:

While protecting long lines the necessary reach may be so large that the minimum service impedance (or load impedance) falls within the region of the starter. This would result in tripping without there being any fault. The two conditions i.e. operation at heavy load and short circuit differ by virtue of phase angle between voltage and current. For the load impedance, the phase angle will be within +30 to -30 Deg. While during short circuits, the fault impedance has a phase angle of 60 to 80 deg. (i.e. line angle).[9]

Load encroachment problem is more pronounced in case of under impedance starters and gets lessened in case of mho, elliptical, lens etc and type of starters. Relays with suitable characteristic on R-X diagram have to be carefully chosen to protect long and heavily loaded lines, and this becomes easily possible with microprocessor based numerical relays. Figure 14 below shows the load encroachment in mho relay.

The load resistance vectors area can be represented as the distance protection tripping zone encroachment. This load area settings calculation until now had been made with the determination of the maximal angle of the load vectors (**φ_{max}**) and the minimal load resistance value (**R_{Load}**).

$$Z_{Load} = \frac{U_{min}}{\sqrt{3}\ X\ I_{Max}}, \qquad R_{Load} = Z_{load} \times \cos\ \varphi_{Load}$$

Where: U_{min} - Minimal voltage value
I_{max} - Maximal load current value
Φ_{max} - Maximal load vectors angle value

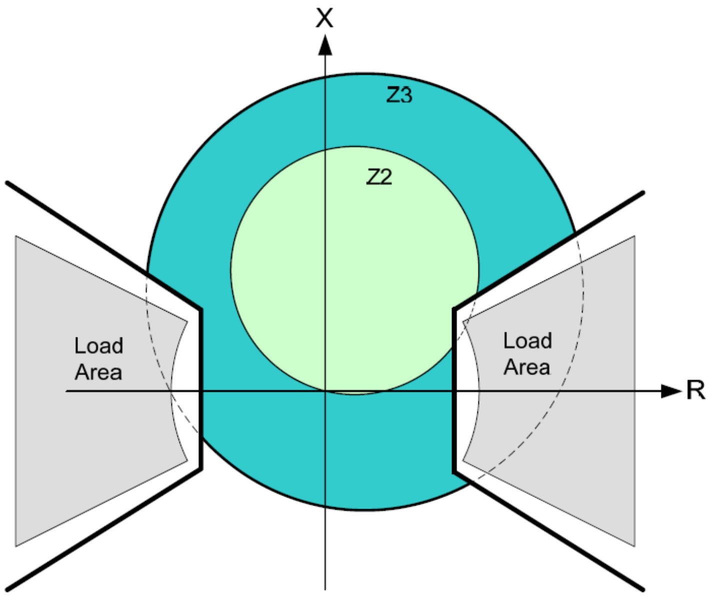


Figure 14: Load Encroachment in Mho relays.[11]

CHAPTER 4

4. METHODOLOGY FOR PROTECTION COORDINATION STUDIES

4.1. Discussion on classical receipt for zone settings:

In Chapter 3, we have presented the definition of distance protection and the idea of parameters (settings) that define operating zones. However, the objective of protection coordination study is to determine those parameters so that protections fulfill the objective of protection systems. It has been mention in Chapter 3 that the objective of protection systems: speed, selectivity, sensitivity and reliability are dependent on the protection coordination study, while speed and reliability are more in the field of manufacturers. In order to achieve the objectives mentioned above, the classical receipt to set the zone settings are:

Zone 1: The protected zone of the first unit is called the Zone 1 of protection. It is high speed unit and is used for the primary protection of the protected line. Instantaneous Zone 1 might not be applicable if the line is too short (less than 10 miles) because short lines have very low impedance that can be within the measurement error of distance relay. Due to this, miss-coordination may occur. Generally the reach of Zone 1 is set between 80% - 90% of the whole length of the protected line with no time delay. The reach of this zone is not 100 % the length of the protected line to avoid the errors due to measurement.[12]

Zone 2: The Zone 2 reach is set to protect the remaining portion of the line left unprotected by Zone 1 and provides an adequate margin. At the same time it provides backup protection for the bus bar in the remote end substation. To coordinate with zone 1 of the relays at remote bus, time delays of 20-30 cycles are typically added to Zone 2 setting, although temporization may vary depending on the circumstances. Usually Zone 2 is set to 120% - 150% of primary protective line. This provides sufficient margin to account for measurement errors.
It is very important to note that Zone 2 also provides back up protection to a part of the adjacent line. In this case, Zone 2 reach can be set one of the following two ways:

- ✓ Zone 2 is set to reach 50% of the shortest back up line provided that $\mathbf{Z_P + 0.5Z_B} > \mathbf{1.2\ Z_P}$; where Z_P and Z_B are the positive sequence impedance of primary and shortest back up line respectively.
- ✓ If $\mathbf{Z_P + 0.5Z_B} < \mathbf{1.2\ Z_P}$, which means that the shortest back up line is too short. In such case Zone 2 is set to $\mathbf{1.2\ Z_P}$

However, in both cases, the calculated reach needs to be checked to ensure that it does not cover beyond the Zone 1 of the next line section.

Zone 3: Even though the transmission line is fully protected with Zone 1 and Zone 2 relays, a third forward reaching zone is often employed.[13] This Zone 3 reach is calculated to act as a backup for Zone 2 and may be applied as remote backup for relay or station failures at the remote terminal. Generally Zone 3 reach is set to 200% of the line impedance, $\mathbf{Z_L}$ with a time delay of 60 cycles or the reach of Zone 3 is set to 100% of $\mathbf{Z_L}$ plus 120% of next longest adjacent line $\mathbf{Z_{L2}}$. This is shown in mathematical form as below:

Zone 3 = $\mathbf{Z_L + 1.2Z_{L2}}$

The resistive reach of the Zone 3 setting should check that the reach does not limit the load carrying capability of the line. Therefore it is very important to verify that the Zone 3 relay does not trip on load under extreme conditions.

4.2. What should detect distance protection?

It is wrongly believed that distance protection should cover every fault inside its operating zone, that is, zone 1 should operate for every fault up to the 80% of the line, zone 2 up to 120 of the line and so on. The setting of distance relays should ensure that they are not going to operate when not required (security) and will operate to trip when necessary (dependability). However, the influence of infeed effect makes that distance relay to be less sensitive, especially in the case of resistive faults. It is wrong to say, for instance, that if the distance relay is 50 ohms, then it should detect faults with resistances of 50 ohms, as was shown in chapter 3. Due to infeed effect, distance relay's performance is poor for high impedance faults. Therefore, a reasonable goal has to be set for the faults detection. This will be shown in the following sections.

4.2.1. Fault Detection Criteria:

As discuss earlier that operating of distance relay has so many factors and one of the most critical factors is fault resistance, since it has different components of fault resistance for overhead transmission line faults. The different components of fault resistance are the tower structure, insulator chains, ground wire and the different impedances to the flow of fault current and are shown in figure 15.[14]

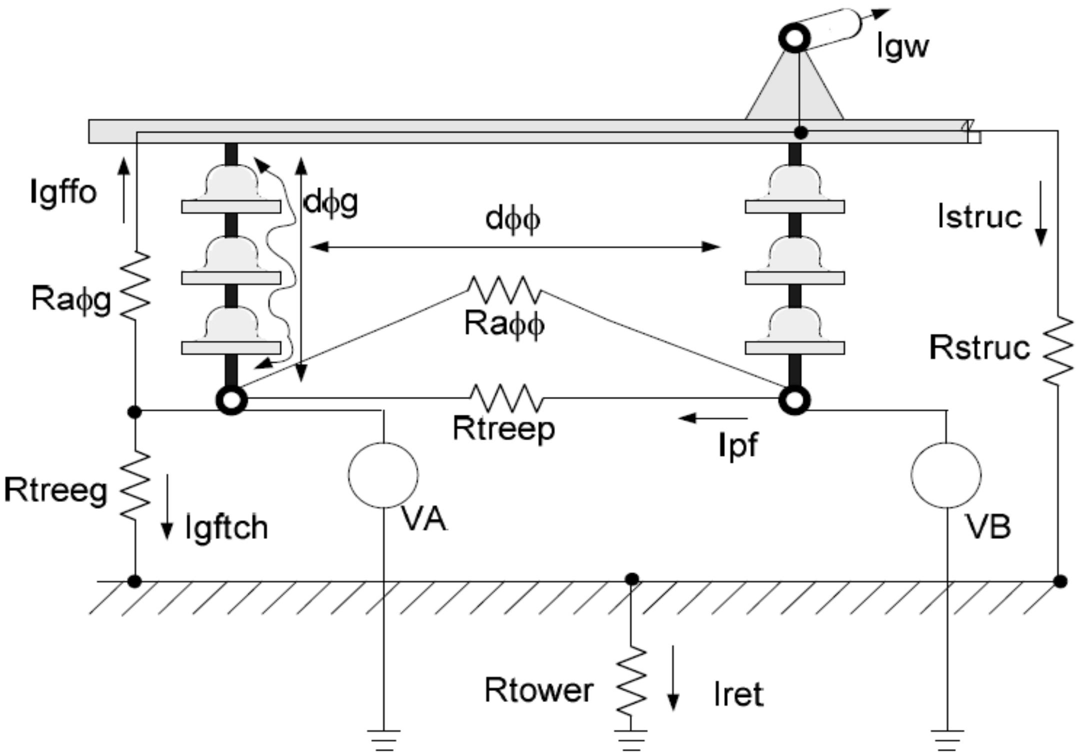


Figure 15: Visualizing the fault resistance (R_F) component [14]

Depending on the nature of the fault, the fault resistance can vary. If the fault is due to a flashover, then the fault resistance would be the sum of the tower footing resistance plus the arc resistance. According to data collected from the transmission utility of Bhutan, the maximum tower footing resistance is around 3.5 ohms.

If the fault is due to an object, like a tree, the fault resistance would be the sum of the tower footing resistance and the object resistance, which is typically very high, in the range of 20 to 50 ohms or even more. It is not practical, then, to set the fault detection criteria so that the relay would detect high impedance due to the reasons stated before. Therefore, in this thesis, the fault detection criteria would be so that the distance relay would detect at least 5 ohm in the whole length of the protected line. This corresponds to faults due to flashovers. As will be shown later, directional earth over current will take the task of detecting high impedance faults. Simulations will be performing to verify that this criterion is fulfilled and simulation result is shown in appendix [C].

4.2.2. Resistive reach of Quadrilateral characteristic:

For adjusting the resistive reach for different zones, as we have seen, a general criterion to select a value for all the different zones of distance protection, allow to establish the coordination between the tripping time of each zone and achieving selectivity. The resistive reach setting for Zone 3 is very important. There is a compromise in the selection of the resistive reach; a large resistive reach would allow the distance relay to detect more faults. However, the larger the resistive reach the more possible that distance relay operates due to load conditions. The figure below shows the quadrilateral characteristic plot for ABB and Siemens make distance relay: [5] [4]

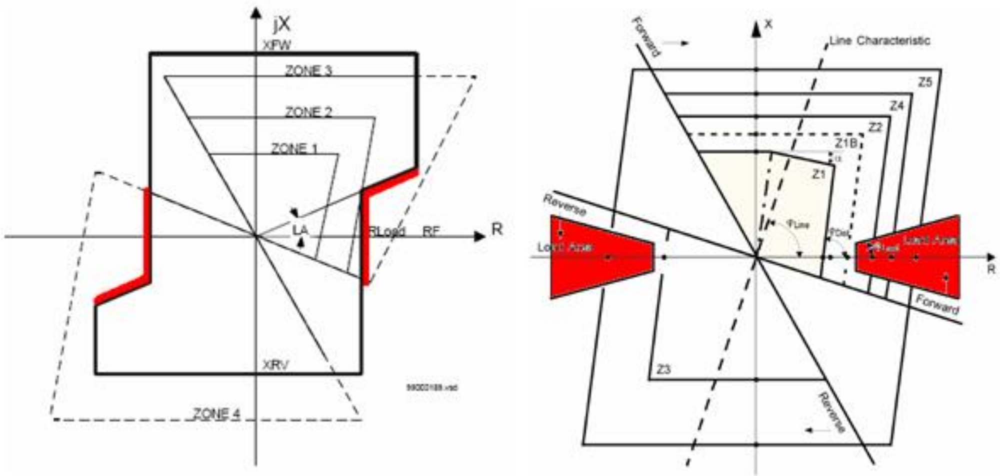


Fig. a Fig. b

Figure 16: Distance relay Characteristics of ABB (Fig. a) and Siemens (Fig. b) relay [15]

The resistive reach does not have to limit the load carrying capability of the line. The resistive ranges are calculated as 45% of the minimum load impedance load. As per the NERC, [11] this ensure that distance relay won't operate when the line is overloaded to 150% of rated thermal current during emergency operation for maximum of 15 minute and considering that the voltage is around 0.85 p.u and the power factor may be greater than 30 degrees, this is considering for the extreme system conditions. During this condition of overloading the system, the protections system should not operate. The minimum load impedance is calculated through the following expression:

$$Z_L = \frac{V_L^2}{MVA_{Rated}}$$

Where: Z_L: Minimum Load impedance in ohms
V_L: Rated Line to Line Voltage in KV
MVA_{Rated}: Thermal rating of Line in MVA

Therefore maximum resistance reach is calculated as: $\boldsymbol{R_{Reach} = 0.45 \times Z_L}$
By using these criteria maximum resistive reach is calculated and checked with simulations for all distance relay and results presented in chapter 5.

4.3. Scenarios to simulate:

The simulation was carried by using CAPE software in different scenarios. For the initial simulation setting provided by the BPC is used and then be derived the new setting values where ever required by taking the consideration of the above mention factors. The simulations were carried out in different scenarios as below:

4.3.1. Scenarios to test sensitivity:

The sensitivity simulation of the distance relay is carried out on two different scenarios, i.e during the peak season and lean seasons of generation. In this simulation effects of infeed on distance relay is also checked and verify the maximum fault resistance that the distance relay could detect the fault. The simulation for one relay is discussed below and details report of the simulation is shown in appendix [C]. The same simulation procedures are followed for rest of the relays.

Case 1: When all the Generator are running with full capacity and without infeed:
The simulation is carried out for the exsiting relay setting with single phase to gorund fault at fault resistance of 5 ohms. In the simulation report as shown below we can see that Zone 1 is detecting the fault of 20%, Zone 2 only 60% and Zone 3 up to 80%of the protective line. Even though zone 1 is set to cove the 80% of the protective line and Zone 2 to cove the 100% of the protective line plus the 20% of the next line. The main reason for non operating of the distance relay is due to low setting coverage of resistive reach for the respective Zone and also due to infeed affect. Hence,the reach of the distance relay varies as a function of fault current distribution, as well as fault location.

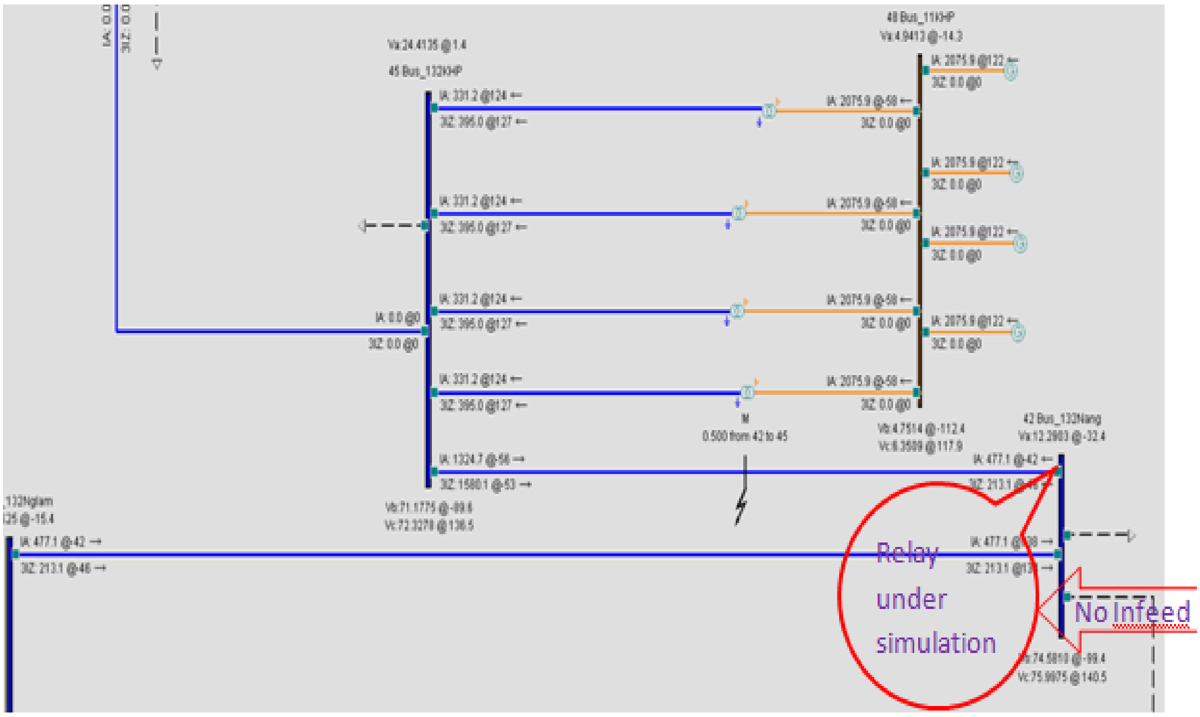
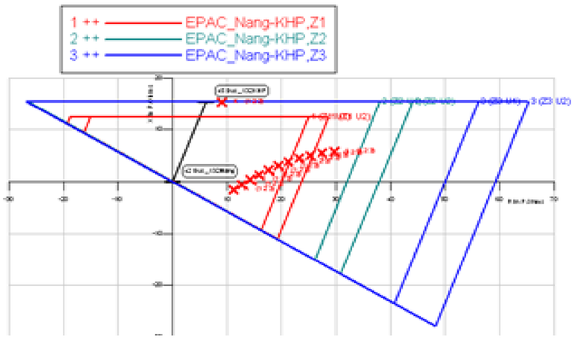
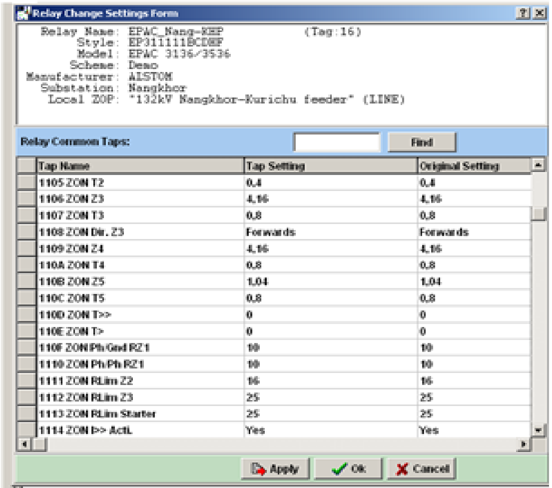


Figure 17: Relay under simulation





Relay Change Settings Form

```
      Relay Name: EPAC_Nang-KHP            (Tag:16)
           Style: EP311111BCDHF
           Model: EPAC 3136/3536
          Scheme: Demo
    Manufacturer: ALSTOM
      Substation: Nangkhor
       Local ZOP: "132kV Nangkhor-Kurichu feeder" (LINE)
```

Relay Common Taps: Find

Tap Name	Tap Setting	Original Setting
1105 ZON T2	0,4	0,4
1106 ZON Z3	4,16	4,16
1107 ZON T3	0,8	0,8
1108 ZON Dir. Z3	Forwards	Forwards
1109 ZON Z4	4,16	4,16
110A ZON T4	0,8	0,8
110B ZON Z5	1,04	1,04
110C ZON T5	0,8	0,8
110D ZON T>>	0	0
110E ZON T>	0	0
110F ZON Ph/Gnd RZ1	10	10
1110 ZON Ph/Ph RZ1	10	10
1111 ZON RLim Z2	16	16
1112 ZON RLim Z3	25	25
1113 ZON RLim Starter	25	25
1114 ZON I>> Actl.	Yes	Yes

Apply Ok Cancel

Simulation Result for 5 ohms fault resistance

```
Study Line:
  From:  Nangkhor        42  Bus_132Nang
    To:  Kurichhu        45  Bus_132KHP

Curve:  1 Substation: Nangkhor
          Relay: EPAC_Nang-KHP EP311111BCDHF DIST "Z1" Zone 1

Curve:  2 Substation: Nangkhor
          Relay: EPAC_Nang-KHP EP311111BCDHF DIST "Z2" Zone 2

Curve:  3 Substation: Nangkhor
          Relay: EPAC_Nang-KHP EP311111BCDHF DIST "Z3" Zone 3

-----------------------------------------------------------------------------------------------
   Fault     Fault  -------CURVE  1-------   -------CURVE  2-------   -------CURVE  3-------
  Location   Code   OPER. SEC    APP. IMP    OPER. SEC    APP. IMP    OPER. SEC    APP. IMP
-----------------------------------------------------------------------------------------------
  Close_in     A        0.030  11.38  -8.2       0.430  11.38  -8.2       0.830  11.38  -8.2
     0.100     B        0.030  12.78  -2.6       0.430  12.78  -2.6       0.830  12.78  -2.6
     0.200     C        0.030  14.38   1.6       0.430  14.38   1.6       0.830  14.38   1.6
     0.300     D    99999.898  16.08   4.8       0.430  16.08   4.8       0.830  16.08   4.8
     0.400     E    99999.898  17.88   7.2       0.430  17.88   7.2       0.830  17.88   7.2
     0.500     F    99999.898  19.78   8.9       0.430  19.78   8.9       0.830  19.78   8.9
     0.600     G    99999.898  21.68  10.2       0.430  21.68  10.2       0.830  21.68  10.2
     0.700     H    99999.898  23.78  10.9   99999.898  23.78  10.9       0.830  23.78  10.9
     0.800     I    99999.898  25.88  11.3   99999.898  25.88  11.3       0.830  25.88  11.3
     0.900     J    99999.898  28.08  11.3   99999.898  28.08  11.3   99999.898  28.08  11.3
  Line_End     K    99999.898  17.88  59.4       0.430  17.88  59.4       0.830  17.88  59.4
Remote_Bus     L    99999.898  30.38  11.0   99999.898  30.38  11.0   99999.898  30.38  11.0
-----------------------------------------------------------------------------------------------
```

Figure 18: Simulation result

Case 2: When all the Generator are running with full capacity and with infeed:
In this case the simulation is run with the infeed from the Deothang feeder. Now we can see that the zone coverage of the all the Zones has improved as compare to the case 1. This is happen due to the current contribution from the Deothang feeder, due to which short circuit current flowing through the relay has increased. From this simulation result, we can see that there is no need to increase the resistive reach setting. But we should keep in mind that relay should operate even for the worst system condition. And also resistive reach can increase unless that the reach does not limit the load carrying capability of the line. The simulation result is presented below:

Table 7: Simulation Result for 5 ohms fault resistance

```
Study Line:
  From:  Nangkhor      42 Bus_132Nang
    To:  Kurichhu      45 Bus_132KHP

Curve: 1 Substation: Nangkhor
         Relay: EPAC_Nang-KHP EP311111BCDHF DIST "Z1" Zone 1

Curve: 2 Substation: Nangkhor
         Relay: EPAC_Nang-KHP EP311111BCDHF DIST "Z2" Zone 2

Curve: 3 Substation: Nangkhor
         Relay: EPAC_Nang-KHP EP311111BCDHF DIST "Z3" Zone 3
```

Fault Location	Fault Code	CURVE 1 OPER. SEC	CURVE 1 APP. IMP	CURVE 2 OPER. SEC	CURVE 2 APP. IMP	CURVE 3 OPER. SEC	CURVE 3 APP. IMP
Close_in	A	0.030	6.12@ -4.3	0.430	6.12@ -4.3	0.830	6.12@ -4.3
0.100	B	0.030	7.24@ 7.0	0.430	7.24@ 7.0	0.830	7.24@ 7.0
0.200	C	0.030	8.59@ 14.8	0.430	8.59@ 14.8	0.830	8.59@ 14.8
0.300	D	0.030	10.1@ 20.2	0.430	10.1@ 20.2	0.830	10.1@ 20.2
0.400	E	0.030	11.7@ 23.9	0.430	11.7@ 23.9	0.830	11.7@ 23.9
0.500	F	0.030	13.4@ 26.5	0.430	13.4@ 26.5	0.830	13.4@ 26.5
0.600	G	0.030	15.1@ 28.2	0.430	15.1@ 28.2	0.830	15.1@ 28.2
0.700	H	0.030	16.9@ 29.3	0.430	16.9@ 29.3	0.830	16.9@ 29.3
0.800	I	0.030	18.7@ 29.8	0.430	18.7@ 29.8	0.830	18.7@ 29.8
0.900	J	99999.898	20.6@ 29.9	0.430	20.6@ 29.9	0.830	20.6@ 29.9
Line_End	K	99999.898	17.8@ 59.4	0.430	17.8@ 59.4	0.830	17.8@ 59.4
Remote_Bus	L	99999.898	22.5@ 29.6	0.430	22.5@ 29.6	0.830	22.5@ 29.6

The resistive reach setting for all the Zones are increased and check that the reach does not limit the load carrying capability of the line. The maximum resistive reach of the line is calculated and compare with the new resistive reach setting of the zone and same is presented in tabular form in Chapter 5. The simulation result after new setting is presented below:

Table 8: Simulation Result for 5 ohms fault resistance for new settings:

```
Study Line:
  From:  Nangkhor      42 Bus_132Nang
    To:  Kurichhu      45 Bus_132KHP

Curve: 1 Substation: Nangkhor
         Relay: EPAC_Nang-KHP(New 2) EP311111BCDHF DIST "Z1" Zone 1

Curve: 2 Substation: Nangkhor
         Relay: EPAC_Nang-KHP(New 2) EP311111BCDHF DIST "Z2" Zone 2

Curve: 3 Substation: Nangkhor
         Relay: EPAC_Nang-KHP(New 2) EP311111BCDHF DIST "Z3" Zone 3

Curve: 4 Substation: Nangkhor
         Relay: EPAC_Nang-KHP(New 2) EP311111BCDHF DIST "Z5" Zone 5
```

Fault	Fault	-------CURVE 1-------		-------CURVE 2-------		-------CURVE 3-------		-------CURVE 4-------	
Location	Code	OPER. SEC	APP. IMP	OPER. SEC	APP. IMP	OPER. SEC	APP. IMP	OPER. SEC	APP. IMP
Close_in	A	0.030	6.12@ -4.3	0.430	6.12@ -4.3	0.830	6.12@ -4.3	99999.898	6.12@ -4.3
0.100	B	0.030	7.24@ 7.0	0.430	7.24@ 7.0	0.830	7.24@ 7.0	99999.898	7.24@ 7.0
0.200	C	0.030	8.59@ 14.8	0.430	8.59@ 14.8	0.830	8.59@ 14.8	99999.898	8.59@ 14.8
0.300	D	0.030	10.1@ 20.2	0.430	10.1@ 20.2	0.830	10.1@ 20.2	99999.898	10.1@ 20.2
0.400	E	0.030	11.7@ 23.9	0.430	11.7@ 23.9	0.830	11.7@ 23.9	99999.898	11.7@ 23.9
0.500	F	0.030	13.4@ 26.5	0.430	13.4@ 26.5	0.830	13.4@ 26.5	99999.898	13.4@ 26.5
0.600	G	0.030	15.1@ 28.2	0.430	15.1@ 28.2	0.830	15.1@ 28.2	99999.898	15.1@ 28.2
0.700	H	0.030	16.9@ 29.3	0.430	16.9@ 29.3	0.830	16.9@ 29.3	99999.898	16.9@ 29.3
0.800	I	0.030	18.7@ 29.8	0.430	18.7@ 29.8	0.830	18.7@ 29.8	99999.898	18.7@ 29.8
0.900	J	0.030	20.6@ 29.9	0.430	20.6@ 29.9	0.830	20.6@ 29.9	99999.898	20.6@ 29.9
Line_End	K	99999.898	17.8@ 59.4	0.430	17.8@ 59.4	0.830	17.8@ 59.4	99999.898	17.8@ 59.4
Remote_Bus	L	0.030	22.5@ 29.6	0.430	22.5@ 29.6	0.830	22.5@ 29.6	99999.898	22.5@ 29.6

4.3.2. Scenarios to test coordination and Sequential operation:

Proper settings of protective relays are essential for the reliable operation of electrical power systems, during both fault and normal system operating conditions. Therefore, it is very much necessary to check the analysis of the ideal operation of protective relays and the identification of incorrect relay operation by Computer simulations. With the help of CAPE software Zone reach of the existing distance relay setting were checked by using Coordination Graphics module and cross checked by running the System Simulation module. The primary intension in conducting this study was to verify the accuracy of the line protection setting. The following study were carried out in three different voltage level, 66kV, 132kV and 220kV as shown in the figure 2 of Chapter 2. The total of 35 numbers of distance relays where carried out system simulation and coordination checking of the relay setting. For the discussion we have selected 66kV Jemina feeder distance relay which is located at Olakha substation. The simulations are carried out in two cases, in case 1 with the existing setting and case 2 with the new settings. The same procedure is followed to all the 35 relays. The simulation result for only 66kV Jemina feeder is presented only, due to large number of pages that attaching the whole simulations results would have meant.

Case 1: Characteristics diagram of Distance relay of the existing setting is plotted by using Coordination Graphics, in which reach of the relay is checked and is shown in the figure 19. The operation of the relay is checked by using the System Simulation, shown in figure 20. During the system simulation the network is consider in normal operation and created single line to ground (SL-G) on the 66kV line between Jemina and Chumdo, which is next adjacent line. During this fault it is found that Distance relay of Olakha end operated in Zone 1 tripping. This shows that improper setting/coordination of distance relay, which can be also seen from the coordination graphics characteristics. The details simulation report is shown in appendix [D].

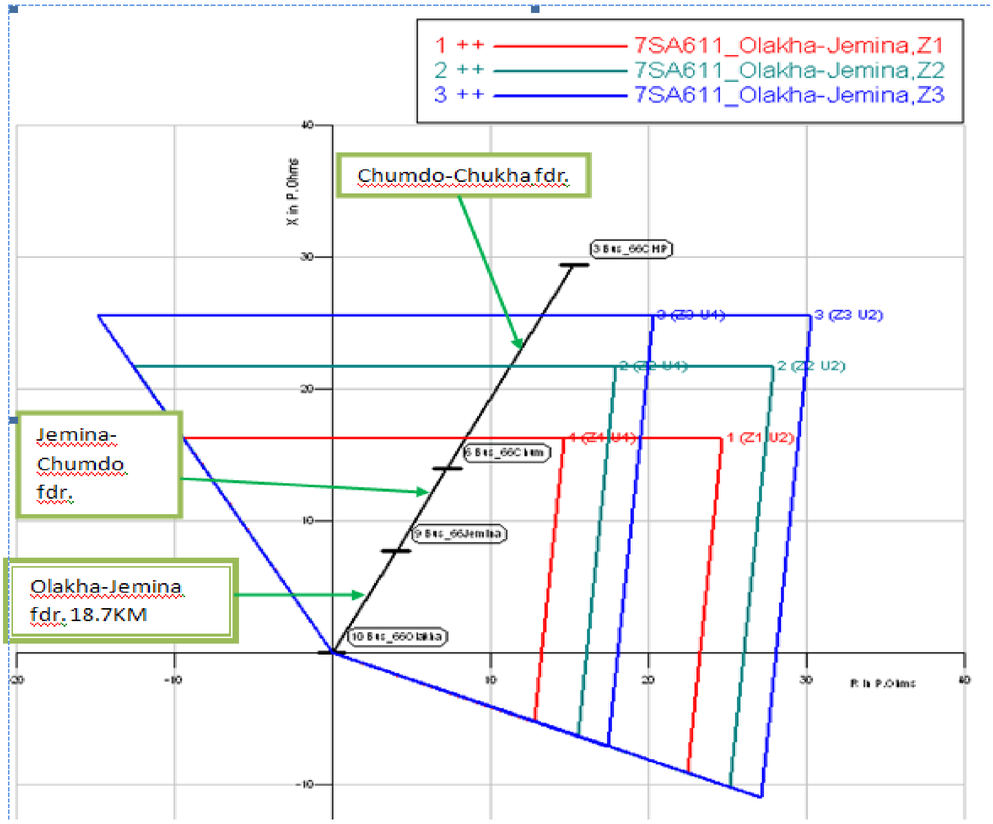


Figure 19: Characteristics plot of existing setting

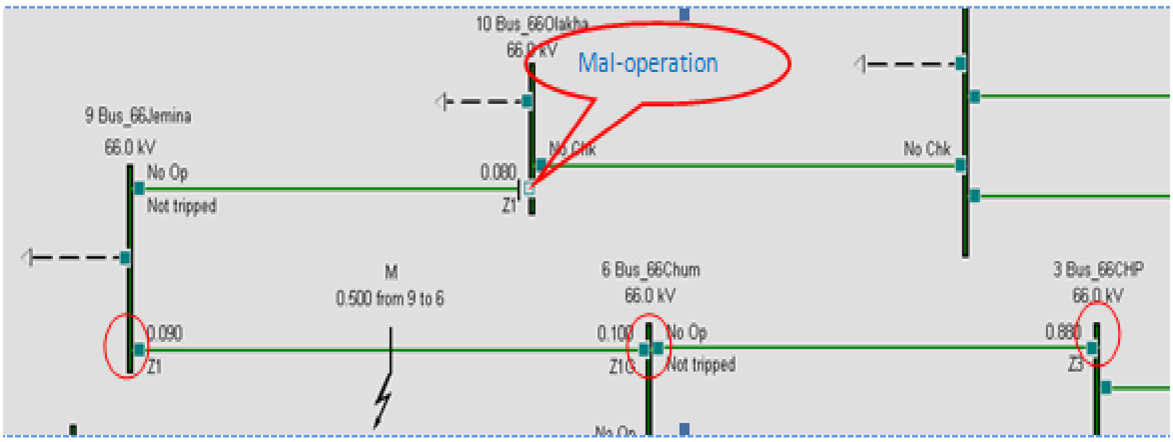


Figure 20: Network showing the fault location and relay operation.

From the above system simulation we can see that there is problem with the setting of the relays. As per the logic, when there is fault between the bus 9bus_66Jemina and 6Bus_66SChum, the relay at 10Bus_66Olakha operate in Zone 1 as shown in figure above. Therefore necessary relay setting changes are made, with help of Coordination Graphics and same is simulated by using System simulation.

Case 2: Characteristics diagram of Distance relay of the new setting is plotted by using Coordination Graphics, after making necessary change in setting is shown in figure 21. Before coming to conclusion the same is checked with the System simulation, by creating the same fault on same line as above, as shown in figure 22.

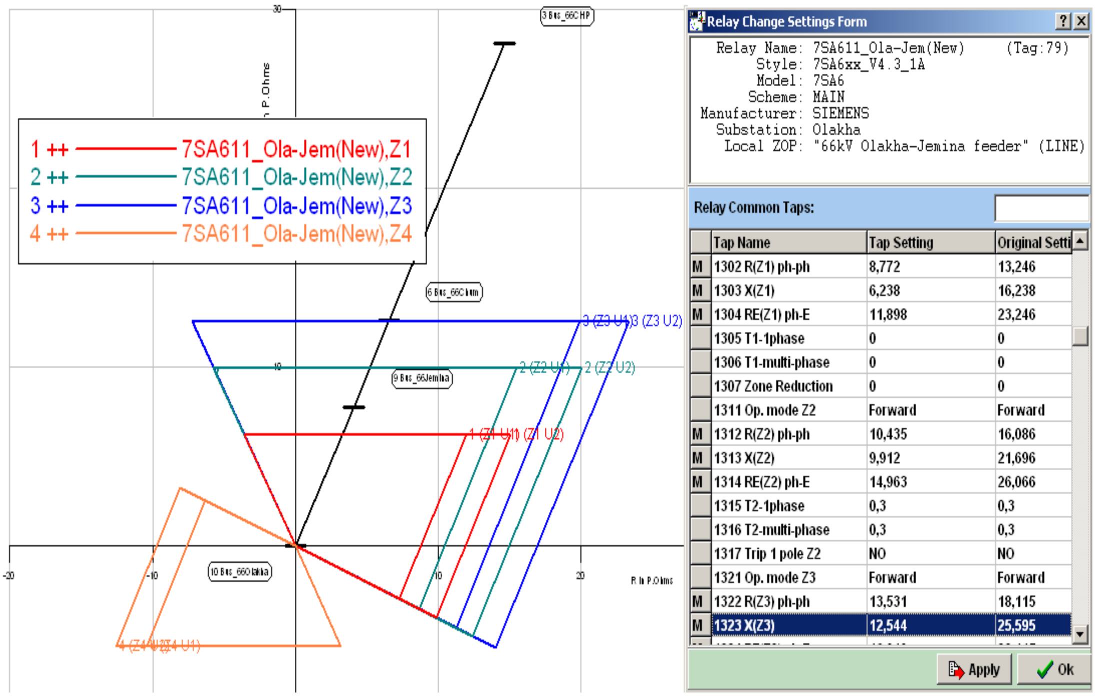


Figure 21: Characteristics plot of new setting

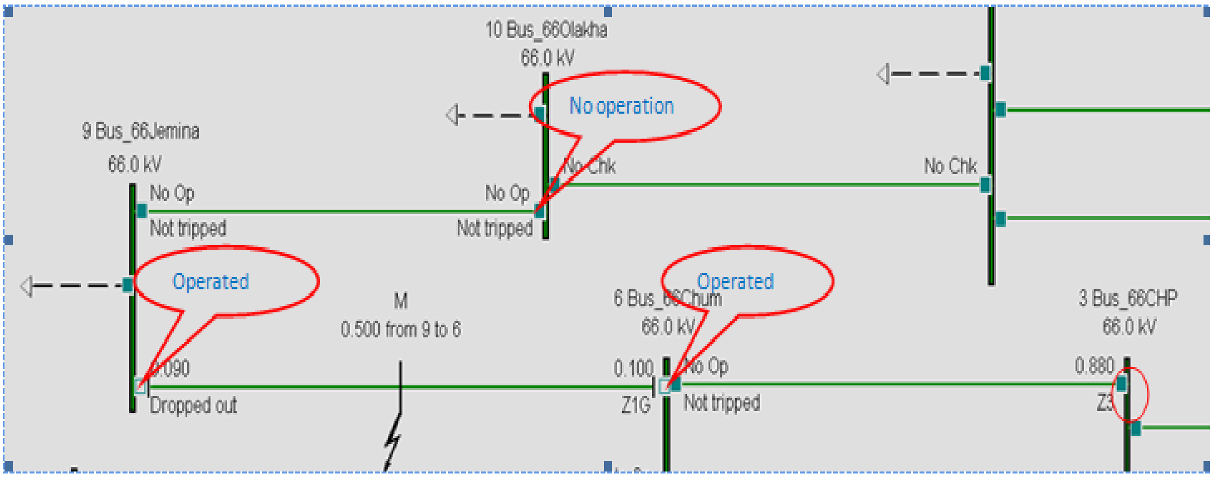


Figure 22: Network showing the fault location and relay operation.

Now we see that both the relay at fault end operated and the relay at Olakha are not operated. The details simulation reports are shown in appendix [D] and new setting table are presented in tabular from in chapter 5.

4.4. Importance of Directional Earth Fault Relay (67N)

In the previous paragraphs it has been shown that the performance of the distance protection is badly affected when the fault resistance increases due to infeed effect. Because of this reason, we have determined that the objective of distance protection is mainly to detect low impedance faults. High impedance faults mainly are the case when an object approaches to the transmission line. Those faults are typically single-phase to ground faults or two-phase to ground faults.

In this type of faults, zero sequence current appears and therefore, directional earth fault relays can be used. Directional earth fault is very sensitive to earth faults and can easily detect those high impedance faults that distance protection can't detect.

Therefore, directional earth fault function is very important since it detects faults that distance relay can't detect. The considerations to set the directional earth fault function are presented in the following sections.

4.4.1. Setting Criteria of 67N:

The coordination of directional earth fault protection is very important to get selective relay operation. Therefore, appropriate criteria to set directional earth fault relays should be determined by the protection engineer as part of an overall protection coordination study. Settings that are too sensitive or too fast may result in non-selective relay operation. If the settings are not sensitive enough, the relay may not detect some faults and this could cause excessive damage in the protection transmission line.

The typical settings for earth fault relays are 30% to 40% of the full load current or minimum earth fault current on the part of the system being protected. However, in Bhutan we usually set earth fault relays 10% to 20% and time delay less than Zone 2 timing. Some time we have to use definite time stage protection setting combined with normal directional earth fault protection for fast tripping. This is use when the fault close to relay, current is much greater than when the fault at the end of the line. This makes a reduction in the tripping time at high fault levels possible, as shown in figure below. The setting of the definite time stage is usually done as:

$$I_{Setting} = \frac{I_A + I_B}{2},$$

Where: I_A : Fault current when the fault near to relay.

I_B : Fault current when the fault at end of line.

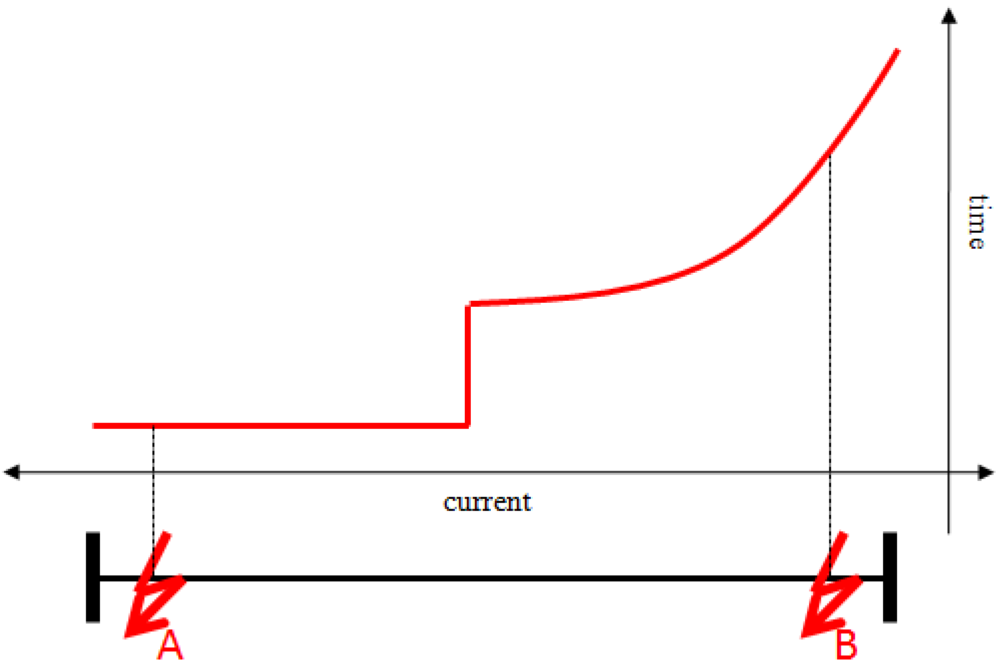


Figure 23: Characteristics of combined IDMT and definite time over current relays.

4.4.2 Simulation showing Importance of Directional earth fault relay:

The single to ground fault apply at 50% of transmission line with a fault resistance of 20 ohms. The simulation was done in two cases, case 1 without Direction earth fault protection and case 2 with directional Earth fault protection. Details simulation results are presented in appendix [E].

Case 1: Without directional earth fault protection:

```
 SS_FAULT_COMMAND: APPLY_SILENT_FAULT SLG_A_R20 NEWBUS1
**********************************************************
*** Starting event # 1
Fault 1 of 1:
Midline node on "12 Bus_66Lobe” to “14 Bus_66Ruri" Ckt 1
"999001 Bus_66Lobe"(NEWBUS1) distant0.500from"12Bus_66Lobe"
SLG_A_R20 at temporary bus "999001 Bus_66Lobe" (NEWBUS1)

Bus & phase pair   Fault current Amps @ deg
999001A -   00              1325.622 @ -43.94

Check by Simulation: open breakers in successive steps
Simulation Area:

Fault is not cleared after     1.0 cycles   0.020 seconds
```

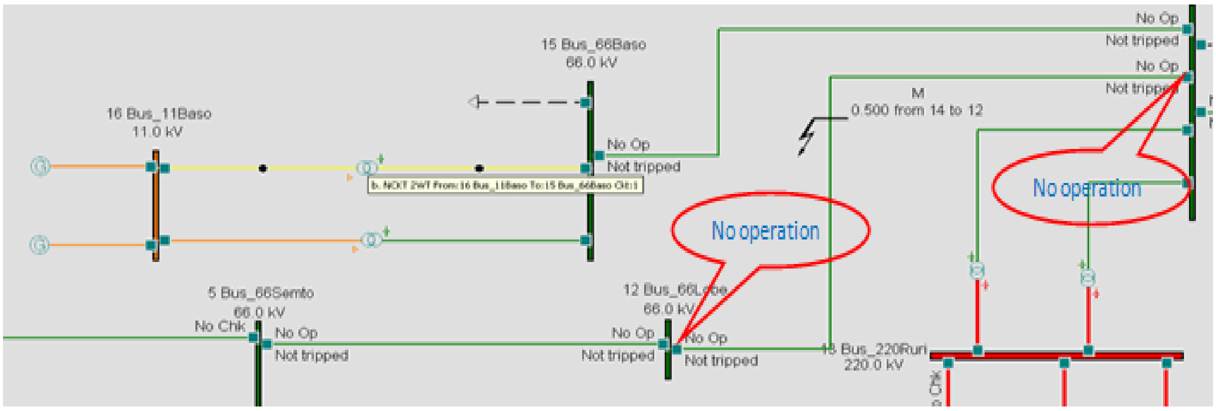


Figure 24: Network showing the fault location and non operation of distance relay.

From above simulation we see that all the distance relay were not detecting the high impedance fault, therefore it is not operated and the fault is not able to clear.

Case 2: With directional earth fault protection:

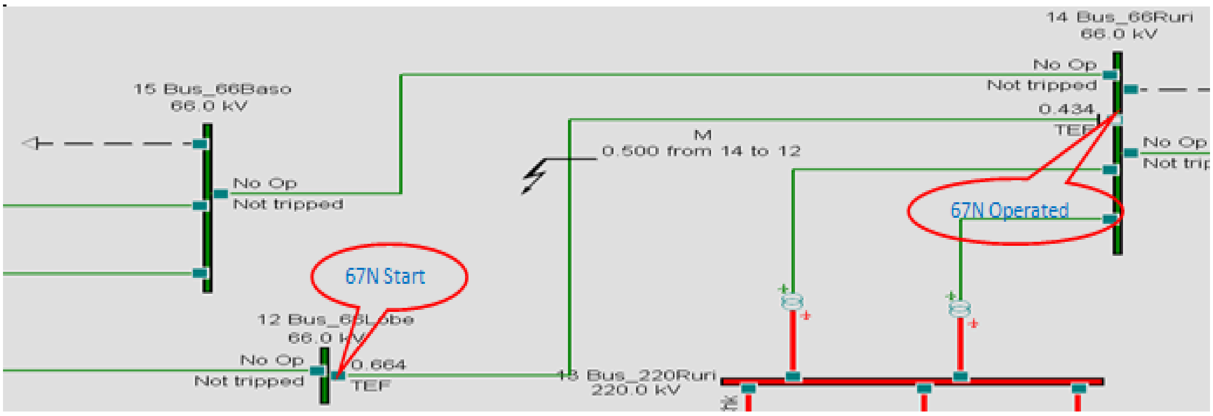


Figure 25: Network showing the fault location and 67N operation.

Now the 67N at source end has operated first and still the fault is not clear in first cycle of simulation. Now the network has become radial feeder and distance zone 1 has operated because Zone 1 is set with no time delay, as u can see in the figure below.

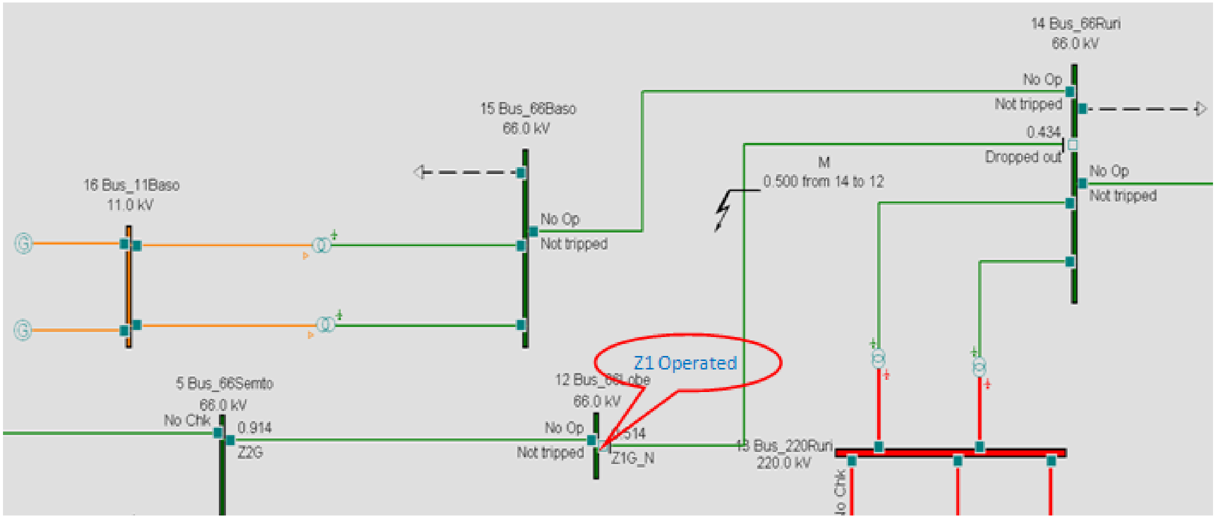


Figure 26: Final Network after fault is cleared and showing the relay operation.

4.4.2. Scenarios to Test Coordination of 67N:

As we all know that basic function of the protection is to detect the faults and isolate these faults by giving trip command to circuit breaker to disconnect the faulty line from the system. However, the protection scheme must be selective so that only faulted element is isolated. Therefore, proper coordination between different relays units is very much necessary, in order to fulfill the selectivity, which is one of the principle function requirement of protection system. Simulation of relay coordination is presented below and details simulation reports are shown in appendix [F].

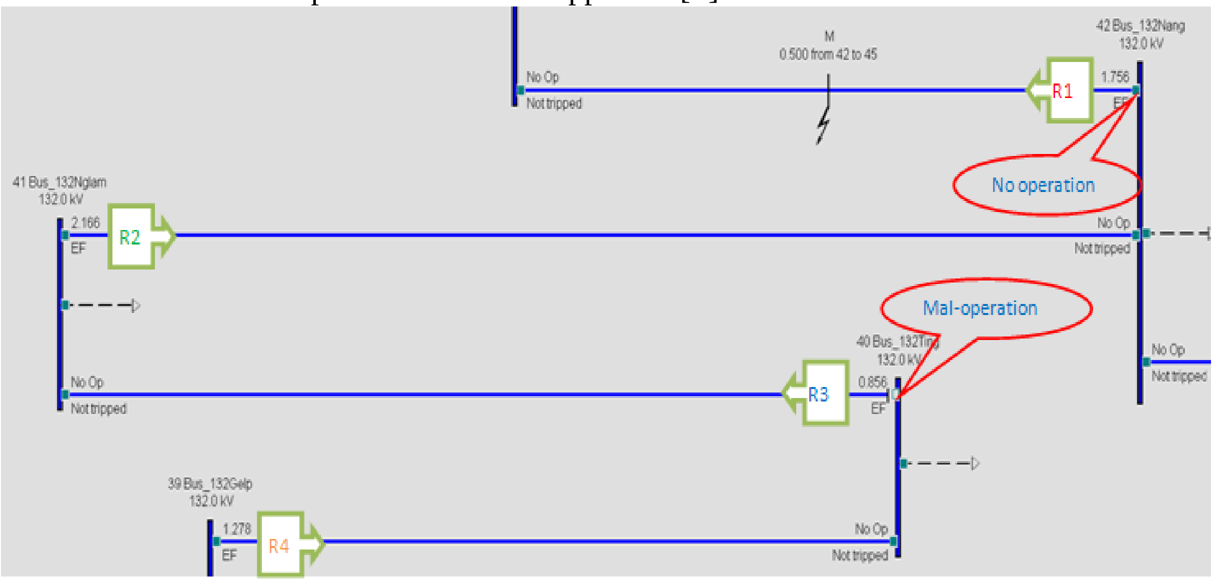


Figure 27: Network showing the fault location and relay operations for existing setting.

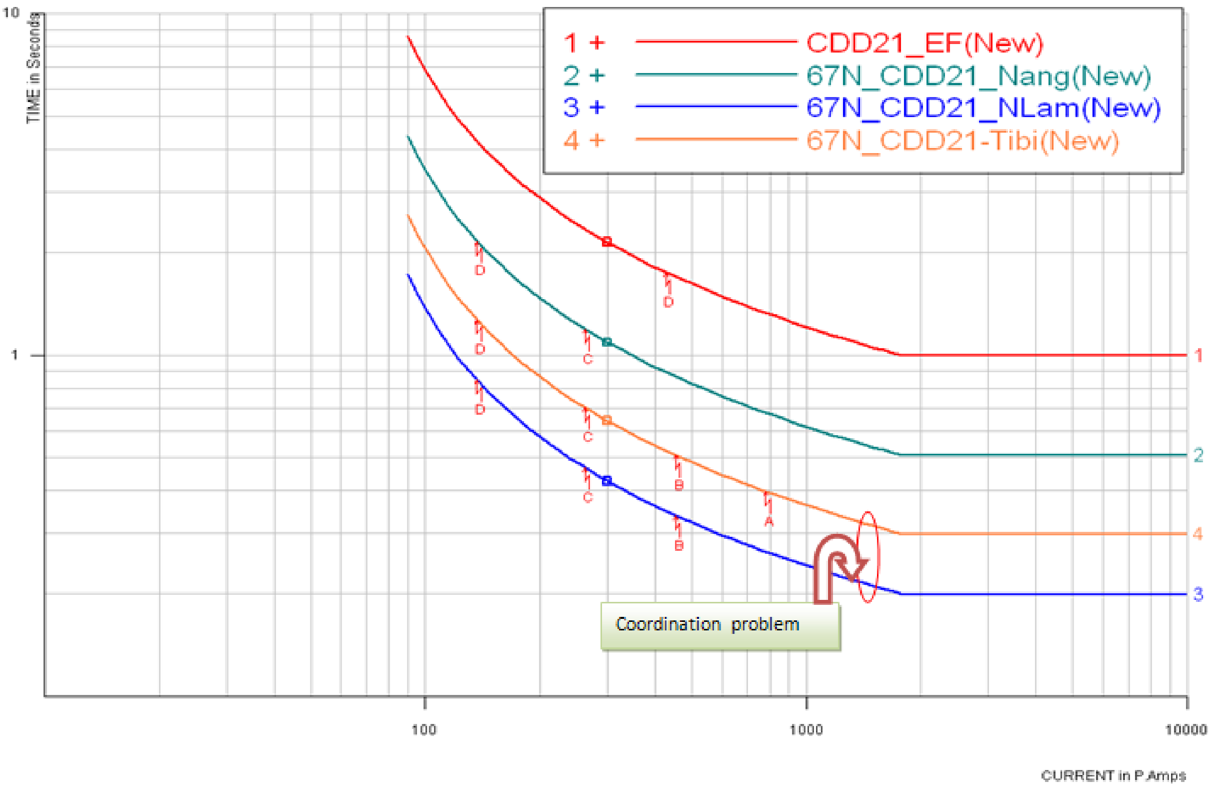


Figure 28: Normal inverse time-characteristic of 67N for existing setting.

Fault: D
SLG_A_R30 at temporary bus 999001 Bus_132Nang (NEWBUS1)
Midline node on "42 Bus_132Nang"to"45 Bus_132KHP" Ckt 1
"999001Bus_132Nang"(NEWBUS1) distant0.501from"**42Bus_132Nang**"

Curve (+ seq SIR)	Current Primary A	A/Pickup	Operating Seconds	Source/Total line
1	428.02	7.13	1.746	2.77 @ 8.0
2	136.28	2.27	2.158	6.44 @ 3.4
3	136.28	2.27	0.846	1.66 @ 6.3
4	136.28	2.27	1.270	2.09 @ 8.4

From the above simulation and from the plots it is found that the relay R3 is not properly coordinate with the other relays. Due to which R3 is operating faster than the other relays, even the fault is not in it jurisdictions. This is also seen in the system simulation too. We see that R3 is operating at this fault (As shown in the network). Therefore, necessary coordination were done by using the coordination graphics module, this is one of main advantage of using CAPE software. In this we don't need to recalculate whole setting, what we can do here just play with the characteristics curve by dragging up and down till we get proper coordination result. After making necessary relay coordination with help of CAPE software, system simulation and relay characteristics plot are shown below and details simulation result in appendix [F].

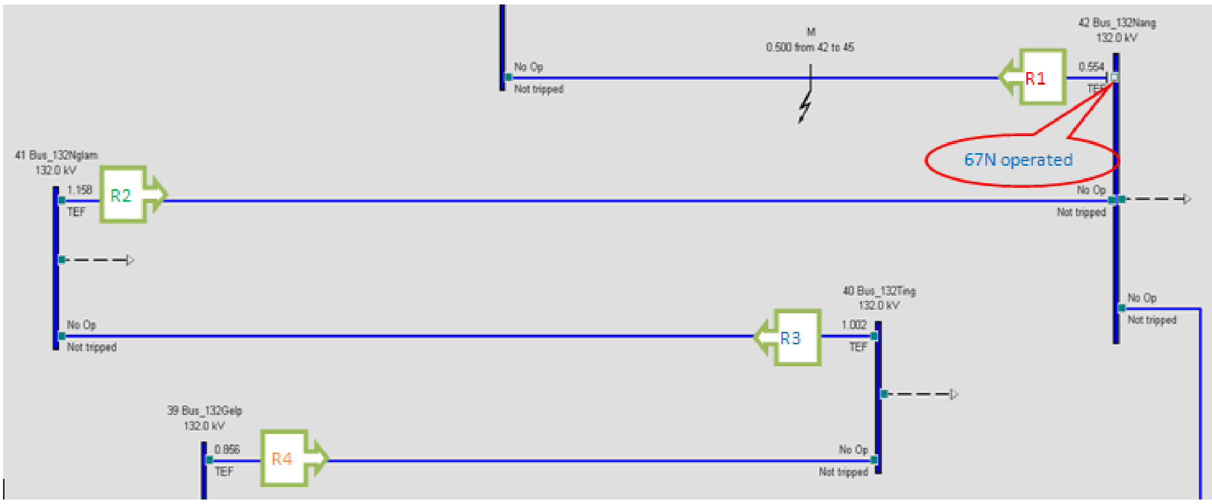


Figure 29: Network showing the fault location and relay operations for new setting

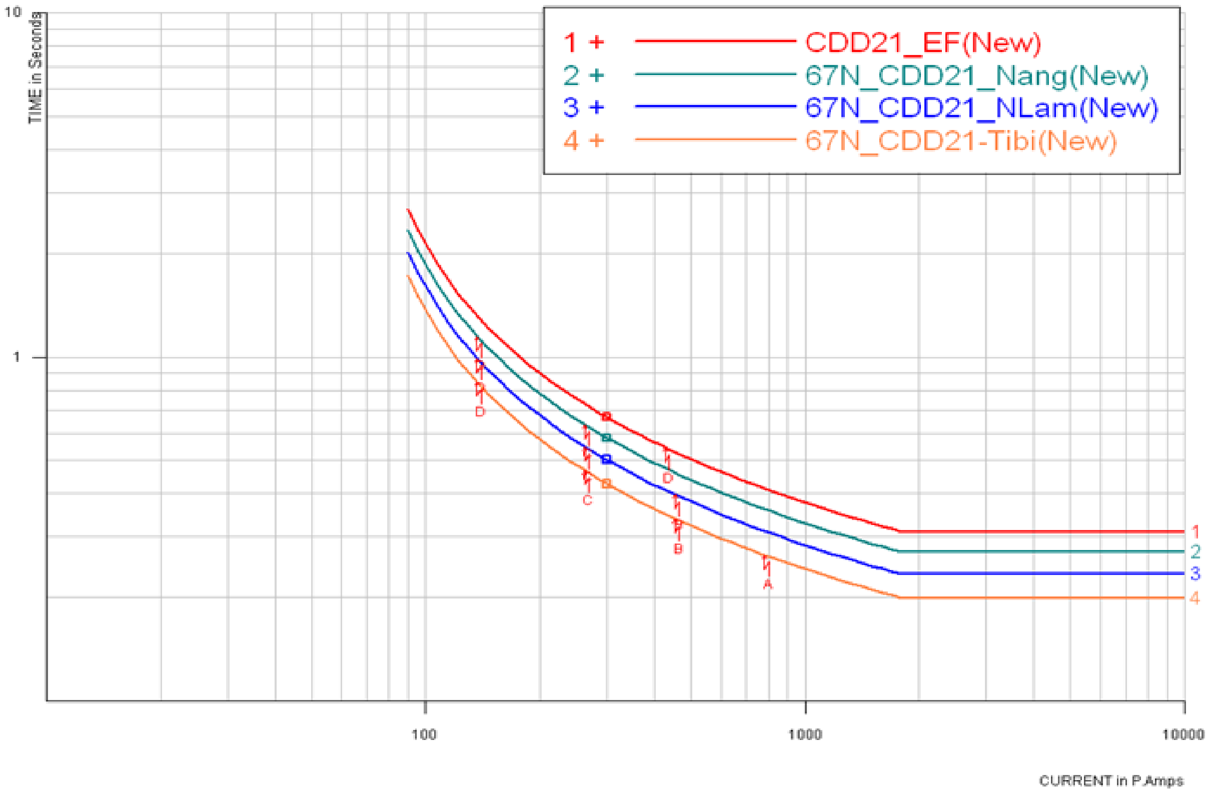


Figure 30: Normal inverse time-characteristic of 67N for new setting

Fault: D

SLG_A_R30 at temporary bus 999001 Bus_132Nang (NEWBUS1)
Midline node on "42 Bus_132Nang" to "45 Bus_132KHP" Ckt 1
"999001Bus_132Nang"(NEWBUS1) distant**0.501**
from"42Bus_132Nang"

Curve	**Current Primary A**	**Operating A/Pickup**	**Seconds**	**Source/Total line (+ seq SIR)**
1 (operated)	428.02	7.13	0.544	2.77 @ 8.0
2	136.28	2.27	1.150	6.44 @ 3.4
3	136.28	2.27	0.992	1.66 @ 6.3
4	136.28	2.27	0.846	2.09 @ 8.4

From the above figure now we can see it is properly coordinated and it is found that only R1 has operated. In this coordination we have not make use of definite time stage function of 67N, since the short circuit current close to relay and at far end are almost equal. The simulation below shows coordination of 67N using the definite time stage function in 220kv feeders:

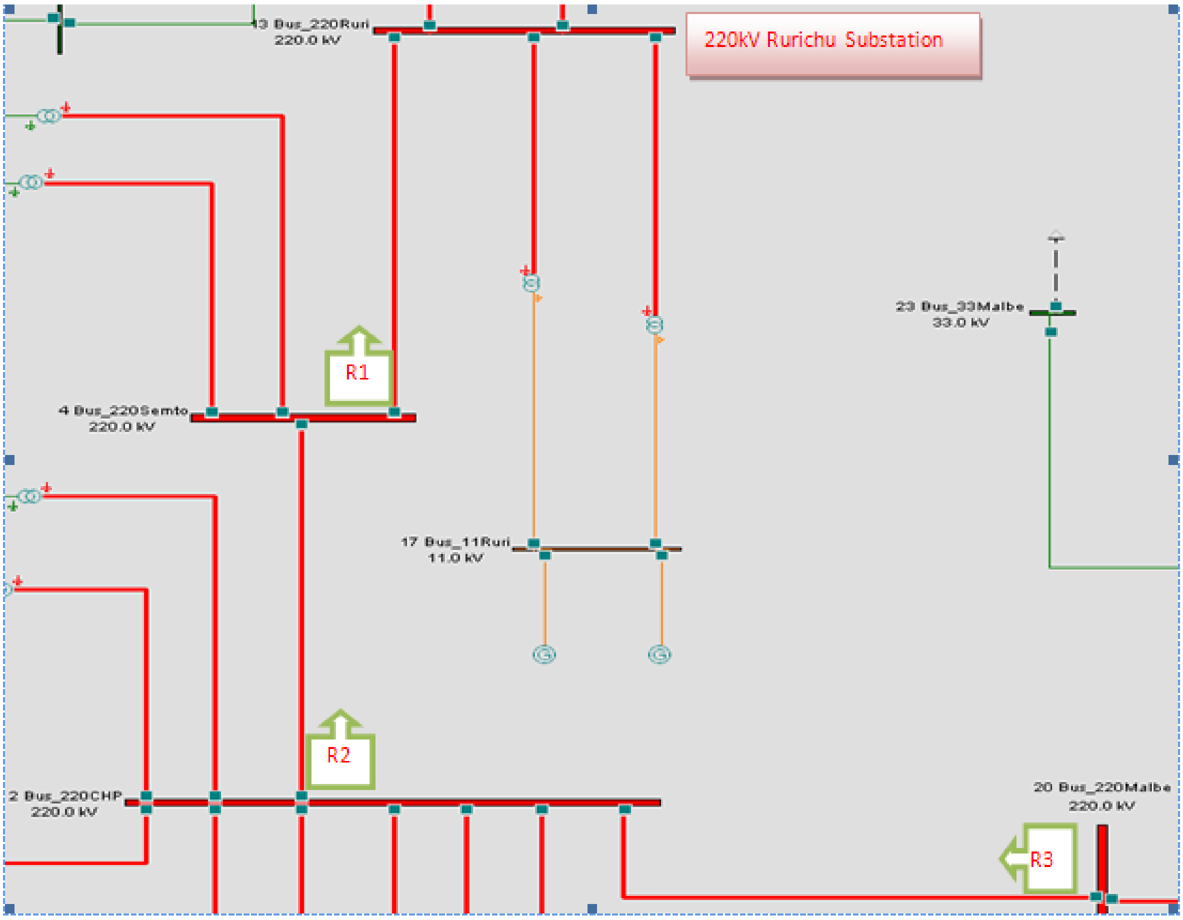


Figure 31: Network showing 67N relay on 220kV feeder looking towards 220kV Rurichu Substation.

Table below show the fault current comparison between the fault close to relay and far away from relay and its operating time.

Table 9: Fault current comparison between two locations:

Relays	**Fault current in Amps**		**Operating time in sec**		**Remarks**
	Close to relay	**Far from relay**	**T-close**	**T- Far away**	
R1	2201.49	1318	0.220	0.260	Fault current difference between close to relay and far end is large. Therefore it takes longer time to isolate the fault.
R2	7484.61	2349.92	0.256	0.296	
R3	4784.30	1578.26	0.298	0.448	

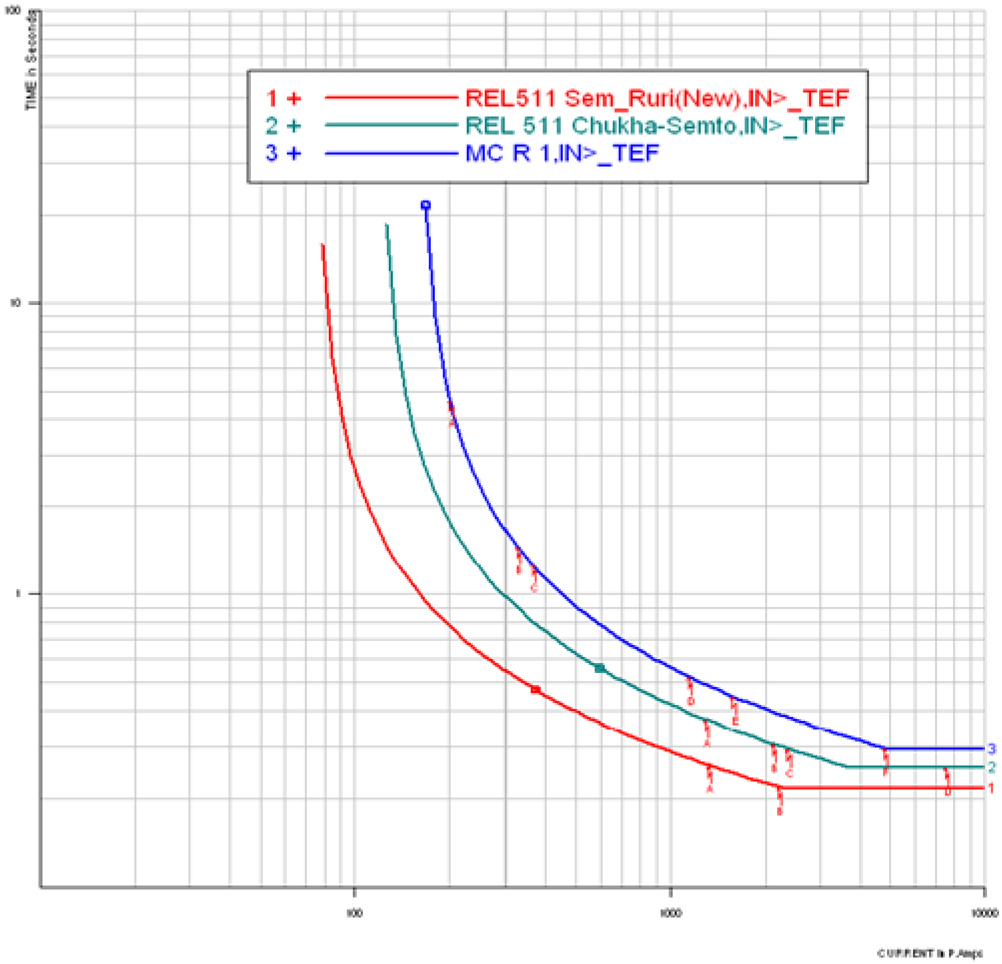


Figure 32: Normal inverse time-characteristic of 67N for existing setting.

From the above coordination graph and simulation, it is found that there is large difference in fault current for the two fault location as mention above. If we only use the normal inverse time characteristics of 67N, then the fault close to relay will take more time to isolate the fault. In this case we need to make use of definite time stage function, so that it will isolate the fault of high current with no time delay. The setting are done as explain above. Now new coordination graph of 67N relay with definite time stage are presented below:

Table 10: Operating of Relay during the fault.

Relays	Fault current in Amps		Operating time in sec		Remarks
	Close to relay	Far from relay	T-close	T- Far away	
R1	2234.99	1318.5	0.196	0.220	DEF operated instantaneously when the fault current is close to relay.
R2	8002.08	2312.98	0.216	0.230	
R3	4954.75	1481.26	0.236	0.326	
DEF1	2234.99	1318.5	0.020	Infinite	
DEF2	8002.08	2312.98	0.020	Infinite	
DEF3	4954.75	1481.26	0.020	Infinite	

Note: R1, R2 & R3 are of normal inverse time earth fault relay (67N), DEF is definite time earth fault relay

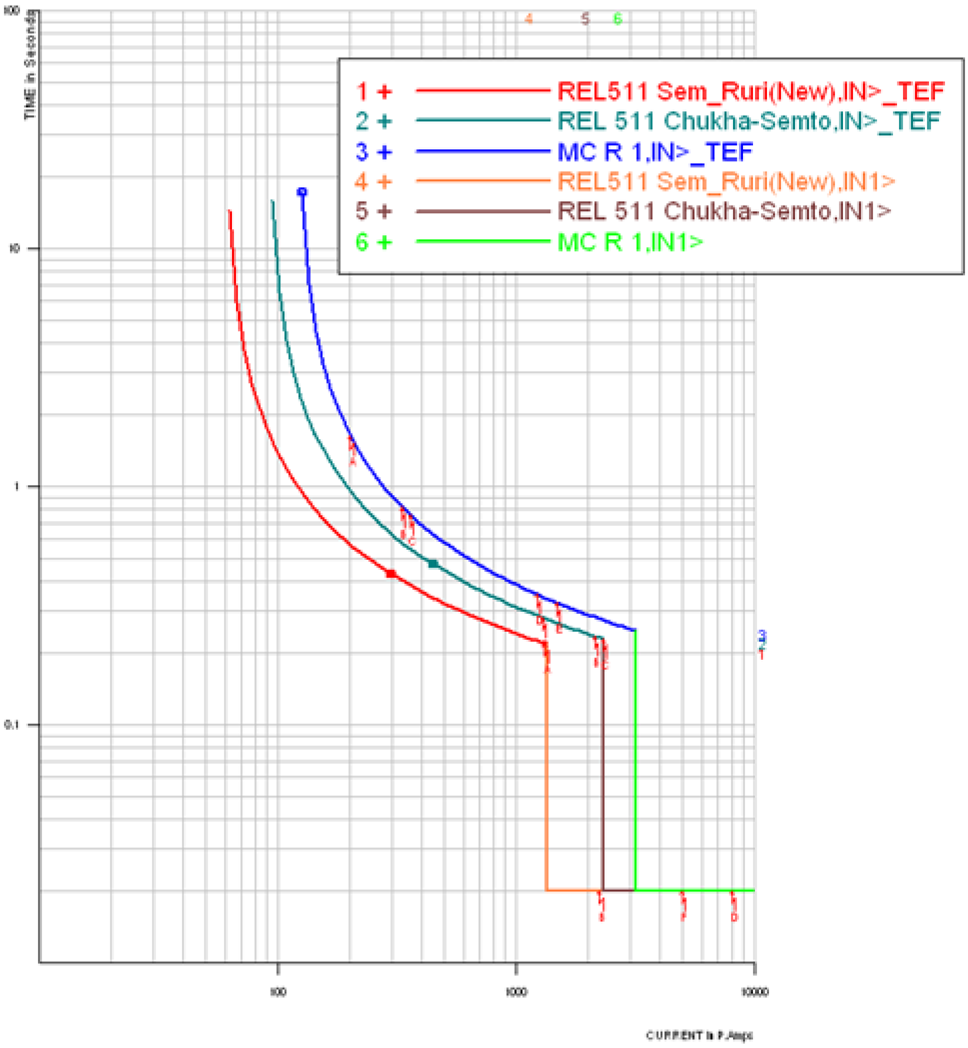


Figure 33: Normal inverse time-characteristic of 67N for new setting with DEF.

CHAPTER 5

5. DISCUSSION ON SIMULATION RESULT

5.1. Introduction:

In this thesis, I have concentrate more on to check the existing relay setting and its coordination. I have tried my best to check as many relay as possible, but due to limited data and time, not able to cover all relay setting checking and coordination. However, I have covered the maximum number of relays and most critical line. Before, I start the relay coordination study; load flow and short circuit study were carried out. The load flow and short circuit study has performed mainly for coordination study of the existing network, in addition to calculate the present load flow and fault levels. Therefore, in this project work, the main discussion has done about coordination analysis of distance relays.

5.2. Software used for the Thesis:

The software tool used is Computer Aided Protection Engineering (CAPE) software. This software is mainly for protection of high voltage transmission system and distribution system within power utilities. This software offers a wide spectrum of applications of protection coordination. In this thesis mainly used One-Line diagram, Short circuit, Power Flow, Coordination Graphics and System Simulator modules.[16]

5.3 Distance Relay setting and coordination study:

In this thesis, detail distance relay coordination and setting were checked with the help of Coordination Graphic and System Simulation module. During the simulation, it was found most of the relays were not coordinate properly and same is rectified. The relay which required major change in setting is presented in table 12 below:

During the collecting the data from Bhutan, it was noted that the method used for zone reach settings are followed different from region to region, base on the relay manufacturer, and the reach are not uniform. Therefore, in order to ensure proper coordination between distance relays in power system, it is customary to choose relay ohms setting should be same. And also in line with Protection and Control Philosophies and IEEE standards for Protection of EHV Lines, the strategy proposed to BPC to adopt distance relay settings is summarized as follows: [13]

Table 11: Proposed Zone settings to be followed in Bhutan network

Sl.No	Zones	Impedance Reach	Time	Direction
1	Zone-1	80% of ZL	Instantaneous	Forward
2	Zone-2	100% of ZL + 40-50% of ZSL	0.3 to 0.4 seconds	Forward
3	Zone-3	100% of ZL + 120% of ZSL	0.6 to 0.8 seconds	Forward
4	Zone-4	100% of ZL + 120% of ZLL	0.9 to 1.5 seconds	Forward/Reversed

Where: ZL = Positive sequence impedance of line to be protected.
ZSL = Positive sequence impedance of adjacent shortest line.
ZLL =Positive sequence impedance of adjacent longest line.

The zone-1 reach is limited to 80% of ZL to provide a reasonable margin against a possible overreach due to errors in CTs, PTs, relay measurement, line parameters, etc. The zone-2 reach is set to cover up to 40-50% of adjoining line so that this will definitely cover the balance 20% of main line (after zone-1 reach) and provides backup to adjoining line relay. Zone-2 setting shall be not less than 120% of ZL in order to ensure definite coverage of 100% of main line. The zone-3 & zone-4 reaches will be suitably set to provide backup for relays on adjacent lines with proper time gradation.

5.4. Calculated/Proposal Impedance for Zones Settings:

Distance relay setting were revised for most of the relay, after it has simulated and checked by Coordination graph. The maximum resistive reach is also checked with the resistive reach limit, which is calculated using equation that is discuss in chapter 4.The detail discussion and justification of existing and proposed settings are explain for one feeder only, since it is follow same principle and also to explain all will be a lot in report. Therefore, I have taken 132 kV Nangkhor feeder for the discussion and justification. For rest of the relays final relay setting are presented in the table 12 below.

132kV Nangkhor feeder at Kurichu Switchyard:

The existing zone settings of the relays for this feeder are not accurate as can be seen from the relay characteristics plot. The zone settings are all set under reach, which means it is not even covering the full line length. This has been justified by system simulation and it is shown below:

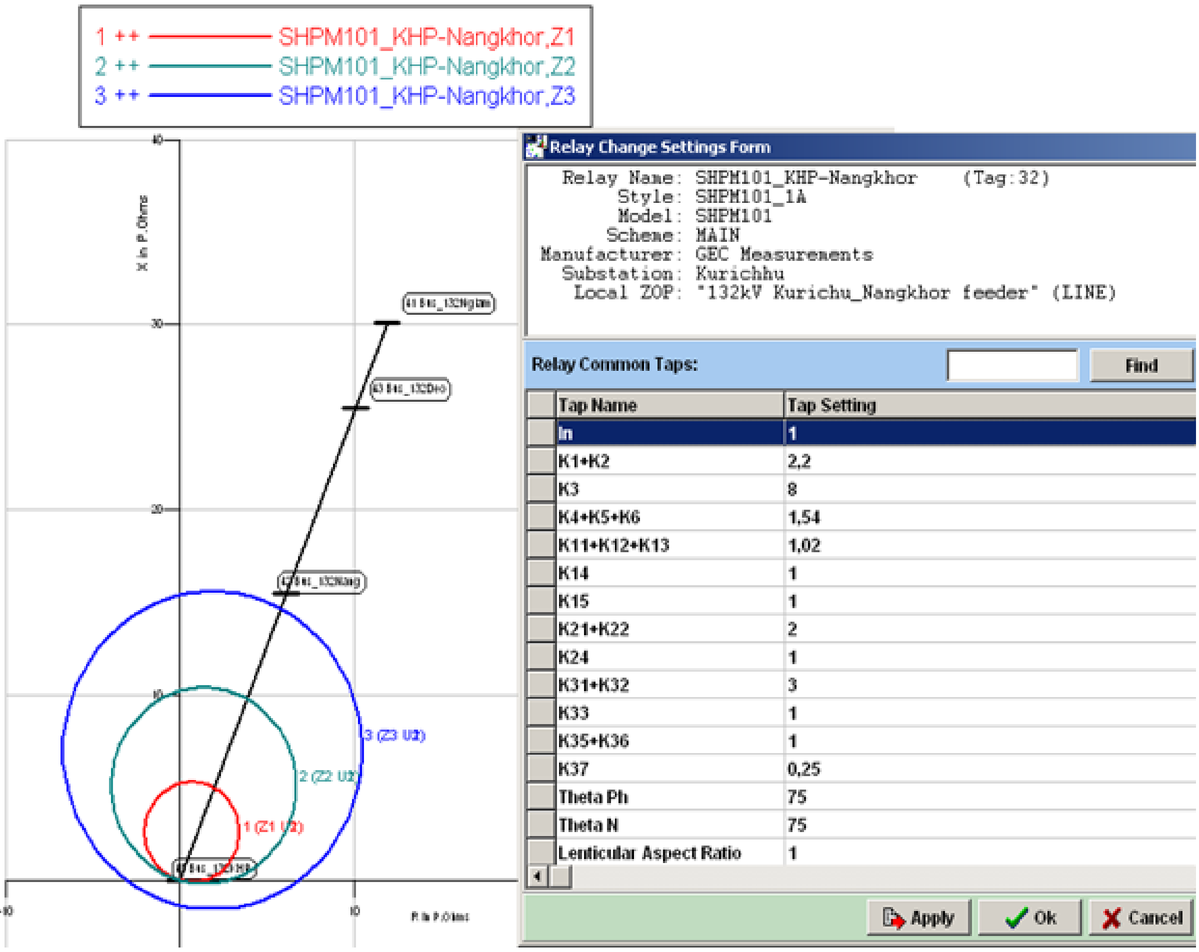


Figure 34: Relay Characteristics plot for existing setting:

During the single phase to ground fault at end of the line, we can see that relay at other end is not able to clear the fault.

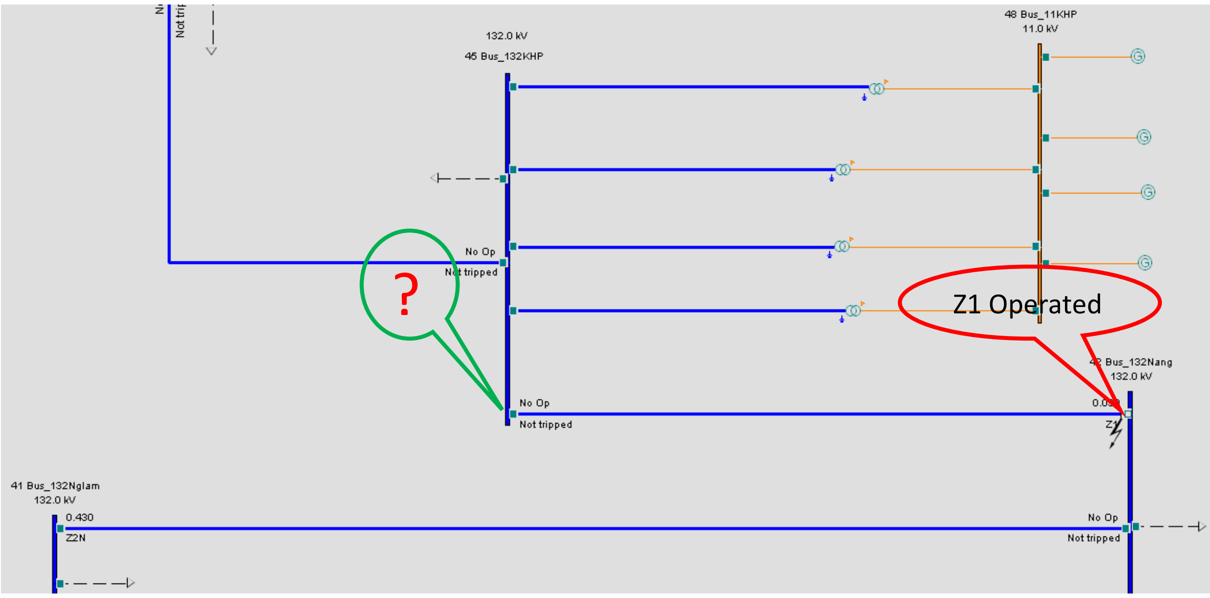


Figure 35: System Simulation for existing relay setting SL-G fault at line end

With existing setting, relay was able to detect the single phase to ground fault at 90% of line length only, which is also by Zone 3 protection, system simulation is shown below. As per the setting criteria Zone 1 should cove 80% of line and zone 2 & 3 are to be cover 100% of line plus backup protection for the next line.

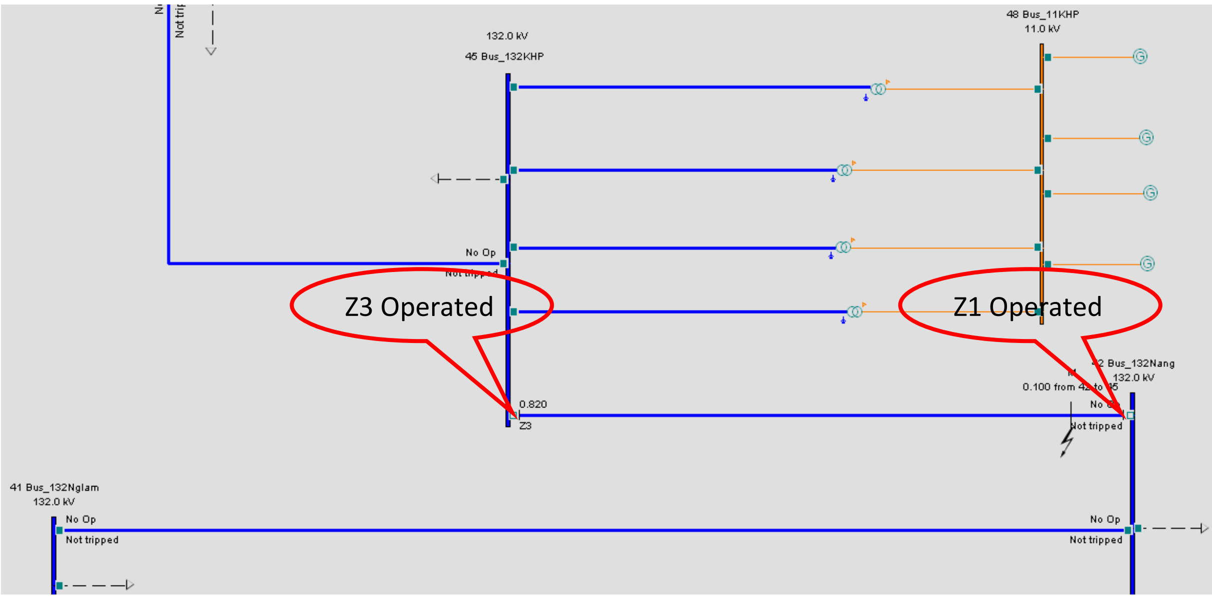


Figure 36: System simulation for existing relay setting SL-G fault at 90% line.

From the above characteristics and system simulation we can clearly see that Zone 1 protection has not set to 80% of the line length and also Zone 2 and Zone 3 are just within the protective line. Due to which it is not able to clear the fault which is close to line end. Therefore new settings have made and relay characteristics plot and system simulation shown below:

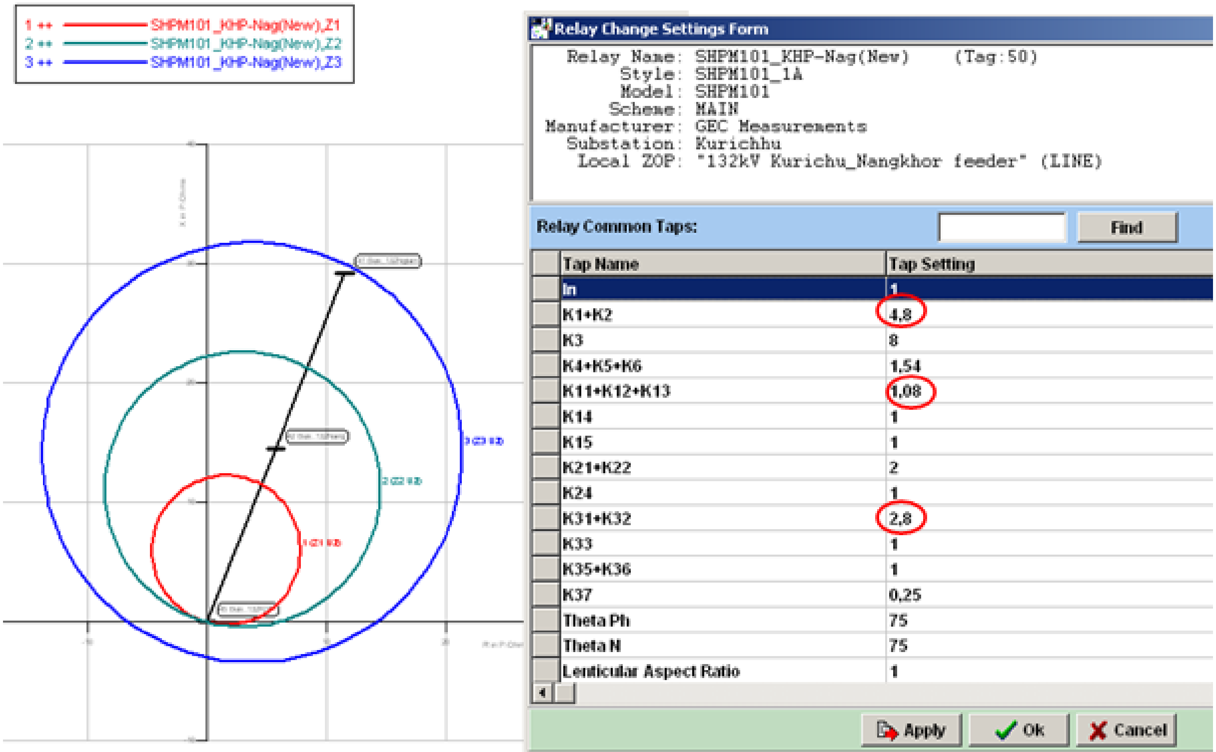


Figure 37: Relay Characteristics plot for new setting:

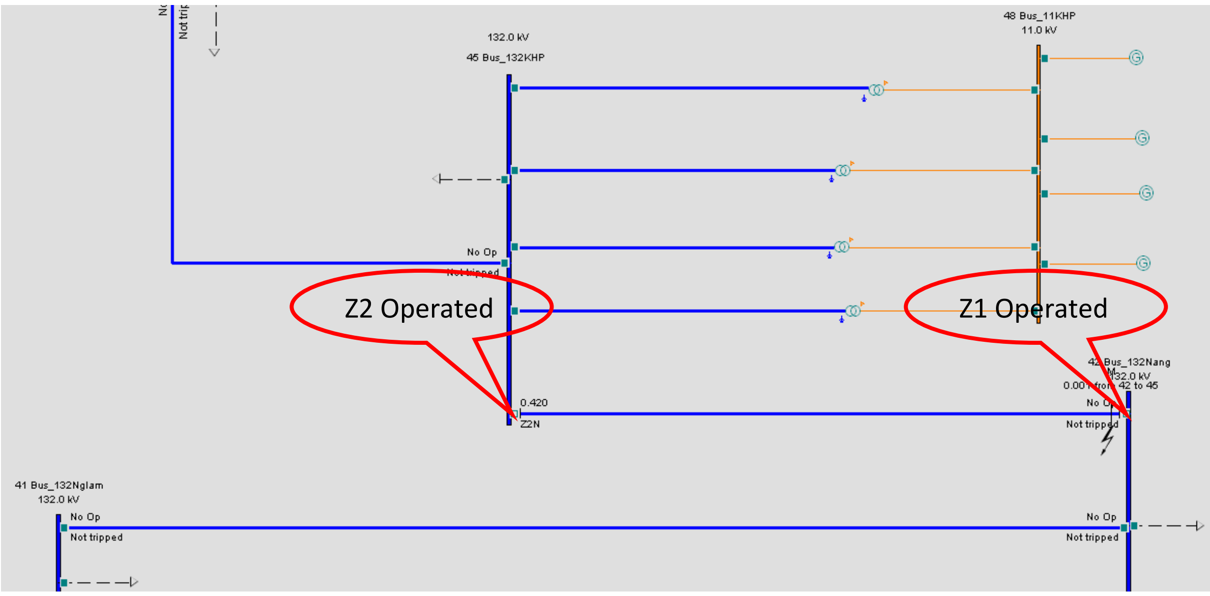


Figure 38: System simulation for new relay setting SL-G fault at end of line.

Table 12: Proposed New relay setting

Name of S/S	Name of feeder	Zone setting in Ω (Sec.)			Resistive Reach in Ω (Sec)			Resistive reach limit in Ω(Sec)
		Z1	Z2	Z3	R1	R2	R3	
Nangkhor	132kV KHP	3.33	4.74	5.31	16.79	19.21	20.07	21.71
	132kV Nanglam	2.86	4.47	14.67	10.0	15.0	15.0	
Nanglam	132kV Nangkhor	3.14	5.18	6.6	7.5	9.2	9.65	
	132kV Tingtibi	7.81	12.2	17.09	4.6	5	5	
Tingtibi	132kV Nanglam	7.68	11.39	13.44	7.53	8.36	8.36	
	132kV Gelephu	4.11	8.15	10.92	4	5	5	
Gelephu	132kV Tingtibi	4.11	7.1	12.95	4	5	5	
Chukha	66kV Chumdo	6.95	10.06	16.54	13.21	14.64	17.64	35.9
Chumdo	66kV Chukha	6.96	11.16	13.63	22.23	26.79	26.84	
	66kV Jemina	2.19	4.93	7.13	12.71	14.30	15.03	
	66kV Paro	4.52	12.41	14.12	5.00	5.63	6.51	
	66kV Haa	6.28	17.27	19.63	5.20	6.38	6.38	
Jemina	66kV Chumdo	1.58	4.07	7.60	4.65	4.65	4.65	23.91
	66kV Olakha	2.27	3.80	4.94	6.50	7.38	7.90	
Olakha	66kV Jemina	7.03	11.17	14.14	11.90	14.96	16.92	71.80
	66kV Semtokha	3.01	4.76	7.38	24.47	24.47	24.47	
Semtokha	66kV Olakha	0.39	1.37	-----	4.00	4.00	-----	35.90
	66kV D/ling	2.22	3.34	5.01	3.85	3.85	3.85	
Lobeysa	66kV Semtokha	4.89	7.34	12.22	19.52	25.00	25.00	
	66kV Rurichu	3.97	8.41	12.36	12.5	14.00	15.00	
Rurichu	66kV Basochu	0.75	2.50	-----	6.01	7.80	----	47.89
Basochu	66kV Rurich	0.75	5.24	-----	12.80	14.18	---	
Semtokha	220kV Rurichu	1.52	2.72	3.54	6.73	7.5	7.5	15.52
Rurichu	220kV Semto	1.85	4.18	5.51	8.52	8.97	9.00	

Where time setting for Zone 1 is instantaneous and Zone 2 & 3 is set 0.4 sec and 0.8 sec respectively.

5.5. Directional Earth fault relay (67N):

During the simulation of high impedance fault, it was found that distance relay are not able to detect the fault, for this protection directional earth fault (67N) is required to isolate the fault. Detail simulation and coordination are presented in chapter 4. In this chapter the summarized relay setting of 67N is shown in the table below.

Table 13: Proposed relay setting of relay type CDD21 for 132kV Eastern Grid.

Name of S/S	Feeder	Relay type	CT ratio	New setting		Characteristics
				Pickup in Amps(sec)	Time dial	
KHP	132kV Nangkhor	CDD 21	500/1A	0.20	0.224	Normal Inverse
Nangkhor	132kV KHP	CDD 21	300/1A	0.20	0.156	
	132kV Nanglam	CDD 21	300/1A	0.20	0.199	
Nanglam	132kV Nangkhor	CDD 21	300/1A	0.20	0.136	
	132kV Tingtibi	CDD 21	300/1A	0.20	0.164	
Tingtibi	132kV Nanglam	CDD 21	300/1A	0.20	0.117	
	132kV Gelephu	CDD 21	300/1A	0.20	0.129	
Gelephu	132kV Tingtibi	CDD 21	300/1A	0.20	0.10	
	132kV Salakati	CDD 21	300/1A	0.20	0.10	

Note: Arrow above indicates the direction of coordination and colour represent the relay group for coordination.

The table below shows the setting of directional earth fault and definite time earth fault function that is inside the REL511 relay: The detail discussion is explained in chapter 4 and settings are presented in appendix [G].

Table 14: Direction Earth fault relay setting:

Substation	Feeder	REL 511 type function enable	CT ratio	Relay setting		Characteristics
				Pickup in Amps(sec)	Time dial	
Semtokha	220kV Rurichu	OC IN>_TEF	300/1A	0.20	0.10	Standard Inverse
		Inst. OC IN1>	300/1A	4.46	....	Definite
Chukha	220kV Semtokha	OC IN>_TEF	600/1A	0.15	0.11	Standard Inverse
		Inst. OC IN1>	600/1A	3.87	....	Definite
Malbesa	220kV Chukha	OC IN>_TEF	800/1A	0.15	0.12	Standard Inverse
		Inst. OC IN1>	800/1A	3.95	......	Definite

CHAPTER 6

6. CONCLUSION, RECOMMENDATIONS & FUTURE WORK

6.1. Conclusion:

The distance relay coordination study was carried out for a real transmission network of Bhutan, but due to lack of data and information not able to carry out for whole network, anyhow tried to cover the maximum relay and most critical transmission line. Since these activities are highly data intensive and it has always been a tedious and time consuming task to collect this data among many users.
In this thesis, the traditional rules applied for choosing the reach of distance relays are reviewed. These rules fail to cover all the different cases of network topology. False operations are experienced in the case of high impedance faults and with high in-feed. They are also experience in the case of a long line followed by a short one or vice versa. All these studies were carried out by using the Coordination Graphics and same is verified by System Simulation.
Therefore this thesis presents an adaptive setting procedure to avoid the above mentioned problems. Base on this, the proposed new zone settings and justifications are discussed and tabulated in chapter 4&5 for those relays. In cases where long feeders are followed by short feeders, it has taken care to ensure discrimination between the zones of back-up protection on adjacent feeders. The operating time settings of zone 2 and zone 3 are made long enough to be selective with zone 2 and zone 3 of adjacent line section and basic principle are considered to ensure selectivity for proper coordination.

In this thesis also discuss the important of directional earth fault relay as back up protection and its coordination. Details simulation were presented in chapter 4 and proposed new setting were shown in table 13 & 14.

After scrutinizing, it is recommended that, existing relay settings should be set according to proposed settings thereby it would be possible to get optimum protection by using the existing relay. This study proposes the proper coordination of relay thereby relay mal-operation will not be happened during the fault. It will be increased the availability of power in terms of reliability of the network.

6.2. Recommendations:

Based on the simulation studies conduct it is recommended to do the following for existing network of protection system:

- ✓ It is very important to follow the same standard zone reach setting criteria for the entire region in Bhutan Network. The proposed zone reach setting standard is presented in table 11.

- ✓ Most of the distances relay setting need to revised, however the author highly recommended to changing the distance relay setting of 132kV Nangkhor feeder at Kurichu end, 66kV Jemina feeder and 66kV Semtokha feeder at Olakha Substation.

- ✓ Directional earth fault relay (67N), type CDD21 are used as back up protection in 132kV Eastern grid is not properly coordinate and need to revise the setting. The proposed new settings are presented in Chapter 5.

- ✓ Directional earth fault function in distance relay are not enable, the author highly recommend enabling the function in the view of its usefulness at detecting the high impedance fault and backup protection at no additional cost. Detail justifications are explained in Chapter 4. Before enabling, it is recommended to do proper coordination study. Due to limited of time, author could carry out coordination for the 220kV feeder only and settings are presented in table 14.

- ✓ New relay settings are prepared for the 66kV feeders which are soon going to install new numerical distance relay of M/S ABB make. Details setting are presented in Appendix [G].

- ✓ All transmission system in Bhutan should have optimal level of protective device with trained personals especially on its applications and its related studies (short circuit and coordination study). It is very high time to have protection software tools for analysis of protection system and system studies. As the Bhutan network is expanding and soon going to have National Grid.

6.3. Future Works:

In order to have a complete picture and a deeper understanding of the protection system of the Bhutan network, it would be appropriate to continue the study as and when the system is upgraded. The study carry out in this thesis can serve as a basis for the establishment of protection system study in Bhutan network. In this thesis, the author had just carried out the study of distance relay setting coordination and important of directional earth fault relay. This is first steep for study of protection system of Bhutan network.

The model built in this thesis can be upgraded by including the upcoming generating plants and new transmission lines. Thus, there is huge scope of future work and improvement of protection system in Bhutan network. Therefore, following studies were recommended for future works.

- ✓ Continue the distance relay coordination studies and directional earth fault relay for the remaining relays.

- ✓ Coordination study of directional over current relay, which are used as back up protection for transmission lines.

- ✓ Study the important of carrier inter trip scheme in distance protection system, such as Permissive Under-reach Transfer Tripping (PUP) Scheme and Permissive Over-Reach Transfer tripping (POP) Scheme.

- ✓ Study the important of mutual impedance affect on distance relay operation for parallel transmission line.

- ✓ Carry out the complete relay coordination for HV substation. Which will includes 11kV out going feeder, transformer feeder, bus bar and HV incomer.

REFERENCES:

[1] http://www.bpc.bt/

[2] http://www.dgpc.bt/

[3] *"Numerical Distance relay Commissioning and Maintenance Guide",* for EPAC 3100/EPAC 3500, Version V5E & V6, Alstom, 1999.

[4] *"SIPROTEC distance Protection",* Manual for the 7SA6, V 4.2, Siemens.

[5] *"Application Manual REL 511*2.3, Line distance protection terminal"* ,ABB, 2001

[6] Royal Government of Bhutan, Department of Energy, *"Power Progress Data",* 2005

[7] C. Rusell Mason, *"The Art & Science of Protection relaying".*

[8] Alstom T&D Energy Automation and Information, *"Network Protection and Automation Guide"* first edition July 2002, Le Sextant, 3 avenue Andre Malraux, 92300 Levallois-Perret. France

[9] Walter. A. Elmore, *"Protective Relaying Theory and application*", Second Edition

[10] M.V.S Birinchi and C.Venkateswarlu, *"Handbook for Protection Engineers"*, Engineering Staff College of India.

[11] *"Increase Line Loadability by Enabling Load Encroachment Functions of Digital Relays"*, North American Electric Reliability Council (NERC) Prepared by the System Protection and Control Task Force, December 7, 2005.

[12] M.I. Gilany, Bahaa Eldeen Hasan and O.P. Malik, *"The Egyptian Electricity Authority Strategy for distance relay setting: problems and solutions"*, ELSEVIER Electric Power System Research 56 (2000) 89-94.

[13] *"Power Systems Relay committee (PSRC)"*of IEEE C37.113-1999, IEEE guide for "*Protective Relay applications to Transmission Lines"*

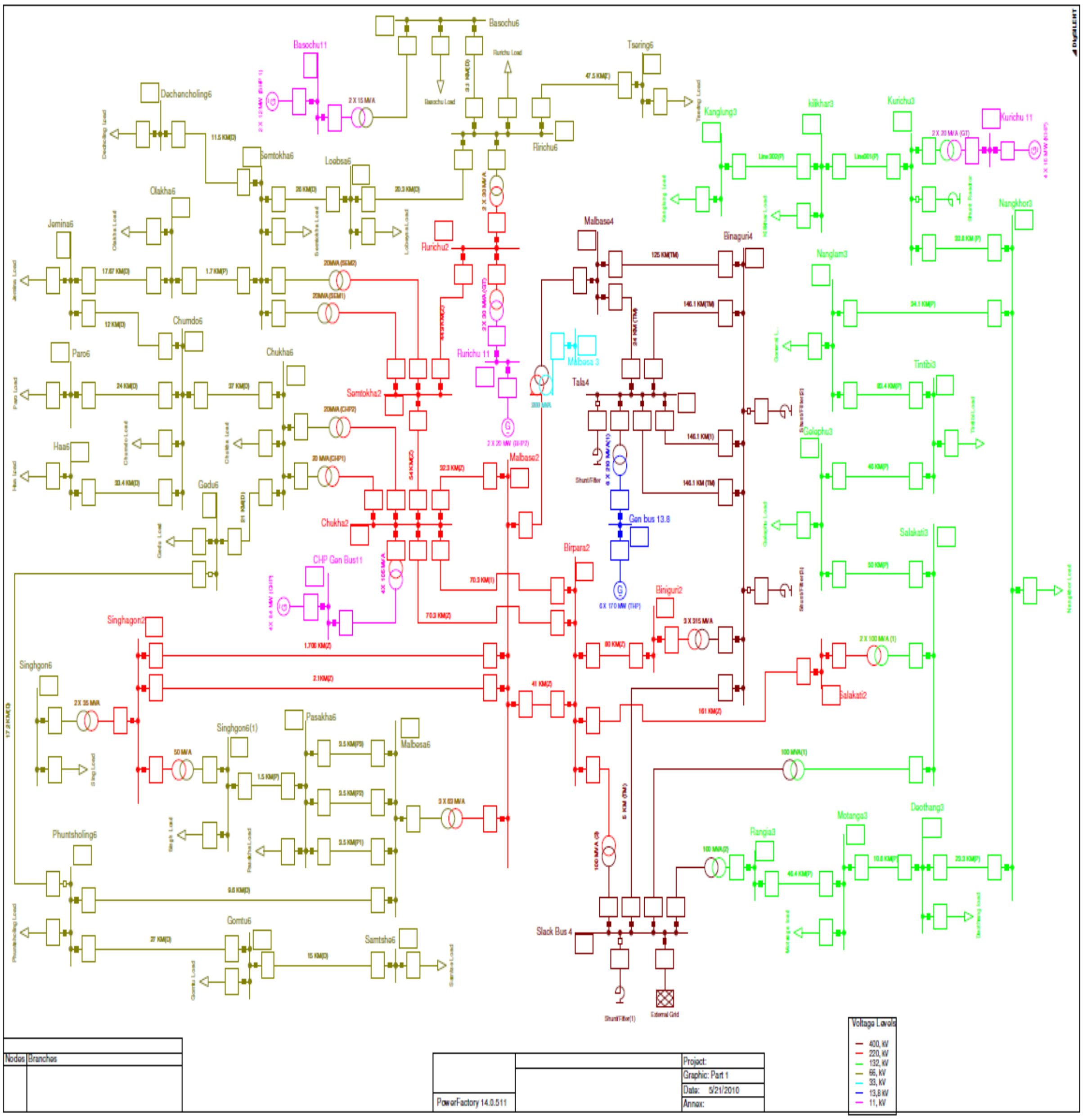
[14] Fernando Calero, Armando Guzman and Gabriel Benmouyal, *"Adaptive Phase and ground Quadrilateral distance Elements"* Schweitzer Engineering Laboratories, Inc. 2009.

[15] K.Brinkis, and D.Drozds, *"Load encroachment resistance settings calculation features for digital distance protection"* CIGRE Relay Protection and Substation Automation of Modern Power Systems, Cheboksary, September 9-13, 2007.

[16] http://www.electrocon.com

APPENDIX:

APPENDIX [A]: Single line diagram of Bhutan network



APPENDIX [B]: Fault MVA and Current for various system Buses during Three phases fault:

CAPE Result:

3PH SC MVA = ABS (sqrt(3)*basekv/1000 * Phase_A_TPH_Fault_Current)

Faulted Bus		--TPH--- IFA	---3ph--- |MVA|
1	Bus_11CHP	173302.6	3301.86
2	Bus_220CHP	8771.8	3342.50
3	Bus_66CHP	4375.1	500.14
4	Bus_220Semto	4098.4	1561.71
5	Bus_66Semto	3847.6	439.84
6	Bus_66Chum	2627.2	300.33
7	Bus_66Paro	1432.0	163.70
8	Bus_66Haa	1227.6	140.33
9	Bus_66Jemina	2758.0	315.28
10	Bus_66Olakha	3680.4	420.72
11	Bus_66Decho	2482.5	283.79
12	Bus_66Lobe	3353.0	383.30
13	Bus_220Ruri	3230.7	1231.07
14	Bus_66Ruri	5006.7	572.35
15	Bus_66Baso	4534.4	518.36
16	Bus_11Baso	18582.0	354.03
17	Bus_11Ruri	35444.7	675.31
18	Bus_66Gedu	3886.5	444.28
19	Bus_66Pling	5754.9	657.87
20	Bus_220Malbe	8080.0	3078.91
21	Bus_66Malbes	10556.3	1206.74
22	Bus_Malbes	8273.6	5732.12
23	Bus_33Malbe	6856.4	391.90
24	Bus_220Singa	7867.5	2997.94
25	Bus_66Singa	3828.2	437.62
26	Bus_66Singa	8917.6	1019.42
27	Bus_66Paskha	9740.5	1113.48
28	Bus_66Gomtu	1852.6	211.78
29	Bus_66Semtsh	1347.0	153.98
30	Bus_13.8Tala	465012.2	11114.86
31	Bus_400Tala	9909.8	6865.69
32	Bus_Binaguri	8501.6	5890.08
33	Bus_220Bina	9718.9	3703.40
34	Bus_220Birpa	8609.4	3280.63
35	Bus_Indian G	7931.3	5494.99
36	Bus_220Salak	2610.3	994.64
37	Bus_132Salak	5093.3	1164.48
38	Bus_132Rangi	2818.8	644.47
39	Bus_132Gelp	2575.4	588.81
40	Bus_132Ting	2070.9	473.47
41	Bus_132Nglam	2192.4	501.24
42	Bus_132Nang	2701.0	617.53

```
43 Bus_132Deo       2515.5     575.12
44 Bus_132Motan     2490.5     569.40
45 Bus_132KHP       2606.2     595.86
46 Bus_132Kili      2254.3     515.40
47 Bus_132Kangl     1607.0     367.42
48 Bus_11KHP       39316.2     749.07
49 Bus_66Tserin     1388.3     158.70
```

Fault MVA for three phase short circuit in DIgSILENT

Name	Grid	Ik" kA	Sk" MVA	ip kA	Ib kA	Sb MVA	Ith kA	Rk, Re(Zk) Ohm	Xk, Im(Zk) Ohm
Basochu11	Part 1	19,07018	363,3358	50,67169	14,94839	284,805	17,78406	0,01868673	0,3325006
Basochu6	Part 1	4,407064	503,7951	10,72158	4,059315	464,042	4,473712	1,401932	8,532703
Binaguri4	Part 1	11,09483	7686,721	28,69446	10,05833	6968,613	11,38639	1,564797	21,07743
Biniguri2	Part 1	11,41728	4350,57	30,186	10,82735	4125,773	11,8185	0,6513231	11,2486
Birpara2	Part 1	10,80486	4117,205	28,17022	10,30707	3927,521	11,11787	1,118705	11,60721
CHP Gen Bus11	Part 1	191,5375	3649,279	521,3746	164,7748	3139,382	187,7708	0,00143167	0,03312631
Chukha2	Part 1	9,664408	3682,634	25,25397	8,967534	3417,089	9,952636	1,361595	13,0111
Chukha6	Part 1	3,194363	365,1648	8,334424	3,166223	361,9479	3,287775	1,686888	11,72634
Chumdo6	Part 1	2,419906	276,6324	4,915104	2,399041	274,2472	2,434447	5,513881	14,13357
Dechencholing6	Part 1	2,244082	256,533	4,608012	2,219759	253,7525	2,258167	6,050753	15,04052
Deothang3	Part 1	3,103454	709,5448	6,703138	2,967883	678,5492	3,127604	6,097391	23,8563
Gedu6	Part 1	1,58557	181,255	3,214522	1,578644	180,4633	1,595028	8,114956	22,25167
Gelephu3	Part 1	2,782622	636,1929	5,740341	2,756502	630,221	2,800418	7,621966	26,576
Gen bus 13.8	Part 1	441,7714	10559,35	1204,919	311,5195	7446,033	414,1245	0,00052011	0,0180277
Gomtu6	Part 1	1,457049	166,563	2,588325	1,453771	166,1884	1,462387	11,77371	19,49907
Haa6	Part 1	1,193563	136,4426	2,223718	1,188514	135,8654	1,198752	12,98512	27,71714
Jemina6	Part 1	2,547125	291,1755	5,191854	2,521522	288,2486	2,562647	5,188532	13,4387
Kanglung3	Part 1	1,715961	392,3213	3,658514	1,597951	365,3406	1,728567	11,95053	43,60215
Kurichu 11	Part 1	40,45857	770,8392	100,0909	31,67958	603,5772	36,77916	0,01783064	0,1559558
Kurichu3	Part 1	2,833371	647,7956	6,615969	2,527867	577,948	2,866198	5,244877	26,92869
Loebsa6	Part 1	3,007893	343,8484	5,992318	2,923294	334,1774	3,024655	4,380975	11,53981
Malbase2	Part 1	8,300515	3162,921	21,1761	7,919558	3017,757	8,48858	2,17611	14,87596
Malbase4	Part 1	9,335758	6468,003	24,55519	8,277462	5734,794	9,639947	1,509822	25,09667
Malbesa 3	Part 1	5,474814	312,9276	15,17285	5,442463	311,0785	6,103495	0,1930095	3,323081
Malbesa6	Part 1	10,34492	1182,584	27,91255	10,16843	1162,407	10,86712	0,5010593	3,502545
Motanga3	Part 1	3,192596	729,9255	6,940072	3,076197	703,3131	3,218176	5,787854	23,14831
Nangkhor3	Part 1	3,124672	714,3961	6,826324	2,922976	668,282	3,15029	5,900753	23,92355
Nanglam3	Part 1	2,415362	552,226	4,957332	2,321525	530,7719	2,430493	9,186419	30,58119
Olakha6	Part 1	3,593213	410,7594	8,494527	3,531314	403,6834	3,638069	2,725978	9,861304
Paro6	Part 1	1,399458	159,9795	2,64194	1,392566	159,1917	1,40584	11,10375	23,39987
Pasakha6	Part 1	9,580409	1095,188	24,95478	9,429105	1077,892	9,854736	0,6560701	3,744458
Phuntsholing6	Part 1	4,066988	464,9192	7,927702	4,039928	461,8258	4,087857	3,478869	7,948891
Rangia3	Part 1	4,879766	1115,664	13,00265	4,804457	1098,446	5,074073	1,029178	15,51499
Ririchu6	Part 1	4,970392	568,1921	12,72916	4,624622	528,6653	5,087573	0,9597611	7,576024
Rurichu 11	Part 1	34,40635	655,5291	92,66511	29,94368	570,5038	33,31728	0,00734507	0,1844375
Rurichu2	Part 1	3,152567	1201,289	7,6098	2,96913	1131,39	3,197678	6,016384	39,76477
Salakati2	Part 1	2,856297	1088,395	7,101401	2,832172	1079,202	2,907391	4,809365	44,23219
Salakati3	Part 1	6,034975	1379,781	15,88031	5,983369	1367,982	6,232833	0,8533529	12,63008
Samtshe6	Part 1	1,048563	119,8668	1,840293	1,046867	119,673	1,052241	16,16958	27,13203
Semtokha2	Part 1	4,289545	1634,536	10,35896	4,069084	1550,529	4,351117	4,541445	29,11712
Semtokha6	Part 1	3,763529	430,2292	9,070367	3,69466	422,3564	3,816805	2,489796	9,452454
Singhagon2	Part 1	8,099005	3086,136	20,59088	7,736005	2947,814	8,276274	2,264409	15,23463
Singhgon6	Part 1	4,024573	460,0704	11,18843	3,998281	457,0649	4,565548	1,462995	8,95074
Singhgon6(1)	Part 1	8,797424	1005,681	22,34259	8,66927	991,0306	8,987965	0,7568677	4,074948
Slack Bus 4	Part 1	17,44244	12084,48	43,8187	16,80825	11645,1	17,78367	1,255427	13,18047
Tala4	Part 1	11,21979	7773,301	29,88131	9,603966	6653,823	10,71208	1,065472	20,89031
Tintibi3	Part 1	2,204822	504,0901	4,404379	2,172269	496,6474	2,217237	10,79976	33,25121
Tsering6	Part 1	1,411355	161,3396	3,271257	1,381877	157,9697	1,427022	4,772557	26,39906
kilikhar3	Part 1	2,445616	559,143	5,517317	2,213791	506,1406	2,469074	6,95989	30,9944

APPENDIX [C]: Simulation result for sensitivity test of Distance relay setting:

Fault Type: SL-G of 5 ohms fault resistance:

Voltage level: 132kV

Simulation Result: Existing setting

```
Study Line:
  From:  Kurichhu        45 Bus_132KHP
    To:  Nangkhor        42 Bus_132Nang

Curve: 1 Substation: Kurichhu
         Relay: SHPM101_KHP-Nangkhor SHPM101_1A DIST "Z1" Zone 1

Curve: 2 Substation: Kurichhu
         Relay: SHPM101_KHP-Nangkhor SHPM101_1A DIST "Z2" Zone 2

Curve: 3 Substation: Kurichhu
         Relay: SHPM101_KHP-Nangkhor SHPM101_1A DIST "Z3" Zone 3
```

Fault Location	Fault Code	-------CURVE 1------- OPER. SEC	APP. IMP	-------CURVE 2------- OPER. SEC	APP. IMP	-------CURVE 3------- OPER. SEC	APP. IMP
Close_in	A	0.020	3.94@ 3.4	0.420	3.94@ 3.4	0.820	3.94@ 3.4
0.100	B	0.020	4.85@ 22.4	0.420	4.85@ 22.4	0.820	4.85@ 22.4
0.200	C	0.020	6.11@ 34.7	0.420	6.11@ 34.7	0.820	6.11@ 34.7
0.300	D	99999.898	7.56@ 42.6	0.420	7.56@ 42.6	0.820	7.56@ 42.6
0.400	E	99999.898	9.11@ 47.9	0.420	9.11@ 47.9	0.820	9.11@ 47.9
0.500	F	99999.898	10.7@ 51.8	0.420	10.7@ 51.8	0.820	10.7@ 51.8
0.600	G	99999.898	12.4@ 54.6	99999.898	12.4@ 54.6	0.820	12.4@ 54.6
0.700	H	99999.898	14.1@ 56.8	99999.898	14.1@ 56.8	0.820	14.1@ 56.8
0.800	I	99999.898	15.8@ 58.6	99999.898	15.8@ 58.6	99999.898	15.8@ 58.6
0.900	J	99999.898	17.5@ 60.0	99999.898	17.5@ 60.0	99999.898	17.5@ 60.0
Line_End	K	99999.898	17.7@ 61.9	99999.898	17.7@ 61.9	99999.898	17.7@ 61.9
Remote_Bus	L	99999.898	19.2@ 61.1	99999.898	19.2@ 61.1	99999.898	19.2@ 61.1

Simulation Result: New setting:

```
Study Line:
  From:  Kurichhu        45 Bus_132KHP
    To:  Nangkhor        42 Bus_132Nang

Curve: 1 Substation: Kurichhu
         Relay: SHPM101_KHP-Nag(New) SHPM101_1A DIST "Z1" Zone 1

Curve: 2 Substation: Kurichhu
         Relay: SHPM101_KHP-Nag(New) SHPM101_1A DIST "Z2" Zone 2

Curve: 3 Substation: Kurichhu
         Relay: SHPM101_KHP-Nag(New) SHPM101_1A DIST "Z3" Zone 3
```

Fault Location	Fault Code	-------CURVE 1------- OPER. SEC	APP. IMP	-------CURVE 2------- OPER. SEC	APP. IMP	-------CURVE 3------- OPER. SEC	APP. IMP
Close_in	A	0.020	5.34@ 3.9	0.420	5.34@ 3.9	0.820	5.34@ 3.9
0.100	B	0.020	6.57@ 23.0	0.420	6.57@ 23.0	0.820	6.57@ 23.0
0.200	C	0.020	8.28@ 35.2	0.420	8.28@ 35.2	0.820	8.28@ 35.2
0.300	D	0.020	10.2@ 43.1	0.420	10.2@ 43.1	0.820	10.2@ 43.1
0.400	E	0.020	12.3@ 48.5	0.420	12.3@ 48.5	0.820	12.3@ 48.5
0.500	F	99999.898	14.5@ 52.3	0.420	14.5@ 52.3	0.820	14.5@ 52.3
0.600	G	99999.898	16.7@ 55.1	0.420	16.7@ 55.1	0.820	16.7@ 55.1
0.700	H	99999.898	19.0@ 57.3	0.420	19.0@ 57.3	0.820	19.0@ 57.3
0.800	I	99999.898	21.2@ 59.0	0.420	21.2@ 59.0	0.820	21.2@ 59.0
0.900	J	99999.898	23.5@ 60.4	0.420	23.5@ 60.4	0.820	23.5@ 60.4
Line_End	K	99999.898	22.8@ 61.9	0.420	22.8@ 61.9	0.820	22.8@ 61.9
Remote_Bus	L	99999.898	25.9@ 61.6	99999.898	25.9@ 61.6	0.820	25.9@ 61.6

Simulation Result for Existing setting without infeed:

Study Line:
From: Nganlam 41 Bus_132Nglam
To: Nangkhor 42 Bus_132Nang

Curve: 1 Substation: Nganlam
Relay: Main Protection EP311111BCDHF DIST "Z1" Zone 1

Curve: 2 Substation: Nganlam
Relay: Main Protection EP311111BCDHF DIST "Z2" Zone 2

Curve: 3 Substation: Nganlam
Relay: Main Protection EP311111BCDHF DIST "Z4" Zone 4

Fault	Fault	-------CURVE	1-------		-------CURVE	2-------		-------CURVE	3-------	
Location	Code	OPER. SEC	APP. IMP		OPER. SEC	APP. IMP		OPER. SEC	APP. IMP	
Close_in	A	0.030	7.99@	-5.6	0.430	7.99@	-5.5	0.830	7.99@	-5.5
0.100	B	0.030	9.12@	2.5	0.430	9.11@	2.6	0.830	9.11@	2.6
0.200	C	99999.898	10.4@	8.6	0.430	10.4@	8.7	0.830	10.4@	8.7
0.300	D	99999.898	11.8@	13.3	99999.898	11.8@	13.3	99999.898	11.8@	13.3
0.400	E	99999.898	13.3@	16.8	99999.898	13.3@	16.9	99999.898	13.3@	16.9
0.500	F	99999.898	14.8@	19.5	99999.898	14.8@	19.6	99999.898	14.8@	19.6
0.600	G	99999.898	16.4@	21.6	99999.898	16.4@	21.6	99999.898	16.4@	21.6
0.700	H	99999.898	18.0@	23.2	99999.898	18.0@	23.3	99999.898	18.0@	23.3
0.800	I	99999.898	19.7@	24.4	99999.898	19.7@	24.5	99999.898	19.7@	24.5
0.900	J	99999.898	21.4@	25.4	99999.898	21.4@	25.4	99999.898	21.4@	25.4
Line_End	K	99999.898	16.9@	58.9	0.430	16.9@	59.0	0.830	16.9@	59.0
Remote_Bus	L	99999.898	23.1@	26.1	99999.898	23.1@	26.1	99999.898	23.1@	26.1

Simulation Result for Existing setting with infeed:

Study Line:
From: Nganlam 41 Bus_132Nglam
To: Nangkhor 42 Bus_132Nang

Curve: 1 Substation: Nganlam
Relay: Main Protection EP311111BCDHF DIST "Z1" Zone 1

Curve: 2 Substation: Nganlam
Relay: Main Protection EP311111BCDHF DIST "Z2" Zone 2

Curve: 3 Substation: Nganlam
Relay: Main Protection EP311111BCDHF DIST "Z4" Zone 4

Fault	Fault	-------CURVE	1-------		-------CURVE	2-------		-------CURVE	3-------	
Location	Code	OPER. SEC	APP. IMP		OPER. SEC	APP. IMP		OPER. SEC	APP. IMP	
Close_in	A	99999.898	10.1@	-4.8	0.430	10.1@	-4.7	0.830	10.1@	-4.7
0.100	B	99999.898	11.1@	2.6	99999.898	11.1@	2.7	99999.898	11.1@	2.7
0.200	C	99999.898	12.4@	8.5	99999.898	12.4@	8.6	99999.898	12.4@	8.6
0.300	D	99999.898	13.8@	13.2	99999.898	13.8@	13.3	99999.898	13.8@	13.3
0.400	E	99999.898	15.3@	16.9	99999.898	15.3@	17.0	99999.898	15.3@	17.0
0.500	F	99999.898	16.9@	19.8	99999.898	16.9@	19.9	99999.898	16.9@	19.9
0.600	G	99999.898	18.6@	22.1	99999.898	18.6@	22.1	99999.898	18.6@	22.1
0.700	H	99999.898	20.4@	23.8	99999.898	20.4@	23.8	99999.898	20.4@	23.8
0.800	I	99999.898	22.3@	25.0	99999.898	22.3@	25.1	99999.898	22.3@	25.1
0.900	J	99999.898	24.2@	25.8	99999.898	24.2@	25.9	99999.898	24.2@	25.9
Line_End	K	99999.898	16.9@	58.9	0.430	16.9@	59.0	0.830	16.9@	59.0
Remote_Bus	L	99999.898	26.3@	26.3	99999.898	26.3@	26.4	99999.898	26.3@	26.4

Simulation Result for New setting with infeed:

```
Study Line:
  From:  Nganlam       41 Bus_132Nglam
    To:  Nangkhor      42 Bus_132Nang

Curve: 1 Substation: Nganlam
         Relay: EPAC_Nanglam-Nangkho EP311111BCDHF DIST "Z1" Zone 1

Curve: 2 Substation: Nganlam
         Relay: EPAC_Nanglam-Nangkho EP311111BCDHF DIST "Z2" Zone 2

Curve: 3 Substation: Nganlam
         Relay: EPAC_Nanglam-Nangkho EP311111BCDHF DIST "Z4" Zone 4
```

Fault Location	Fault Code	CURVE 1 OPER. SEC	CURVE 1 APP.	CURVE 1 IMP	CURVE 2 OPER. SEC	CURVE 2 APP.	CURVE 2 IMP	CURVE 3 OPER. SEC	CURVE 3 APP.	CURVE 3 IMP
Close_in	A	0.030	10.1@	-4.8	0.430	10.1@	-4.7	0.830	10.1@	-4.7
0.100	B	0.030	11.1@	2.6	0.430	11.1@	2.7	0.830	11.1@	2.7
0.200	C	0.030	12.4@	8.5	0.430	12.4@	8.6	0.830	12.4@	8.6
0.300	D	0.030	13.8@	13.2	0.430	13.8@	13.3	0.830	13.8@	13.3
0.400	E	0.030	15.3@	16.9	0.430	15.3@	17.0	0.830	15.3@	17.0
0.500	F	0.030	16.9@	19.8	0.430	16.9@	19.9	0.830	16.9@	19.9
0.600	G	0.030	18.6@	22.1	0.430	18.6@	22.1	0.830	18.6@	22.1
0.700	H	99999.898	20.4@	23.8	0.430	20.4@	23.8	0.830	20.4@	23.8
0.800	I	99999.898	22.3@	25.0	0.430	22.3@	25.1	0.830	22.3@	25.1
0.900	J	99999.898	24.2@	25.8	99999.898	24.2@	25.9	0.830	24.2@	25.9
Line_End	K	99999.898	16.9@	58.9	0.430	16.9@	59.0	0.830	16.9@	59.0
Remote_Bus	L	99999.898	26.3@	26.3	99999.898	26.3@	26.4	99999.898	26.3@	26.4

Fault Type: SL-G of 5 ohms fault resistance:
Voltage level: 66kV

Simulation Result for Existing setting:

```
Fault Study Results
Fault type: SLG_A_R5

No network changes specified

Status of Remote End Breaker:  CLOSED
Remote End Breaker Always OPEN for Line-End Fault

Internal supervision of elements is included

Study Line:
  From:  Rurichu        14 Bus_66Ruri
    To:  Basochu        15 Bus_66Baso

Curve: 1 Substation: Rurichu
         Relay: Main Protection REL511_V2.3_1A DIST "ZM1_GND" Zone 1

Curve: 2 Substation: Rurichu
         Relay: Main Protection REL511_V2.3_1A DIST "ZM2_GND" Zone 2
```

Fault Location	Fault Code	CURVE 1 OPER. SEC	CURVE 1 APP.	CURVE 1 IMP	CURVE 2 OPER. SEC	CURVE 2 APP.	CURVE 2 IMP
Close_in	A	99999.898	2.83@	-2.8	0.420	7.32@	3.8
0.100	B	99999.898	2.96@	-0.9	0.420	7.54@	5.8
0.200	C	99999.898	3.10@	0.9	0.420	7.76@	7.7
0.300	D	99999.898	3.24@	2.4	0.420	7.99@	9.3
0.400	E	99999.898	3.38@	3.8	0.420	8.21@	10.8
0.500	F	99999.898	3.53@	5.0	0.420	8.43@	12.2
0.600	G	99999.898	3.69@	6.0	0.420	8.64@	13.4
0.700	H	99999.898	3.85@	6.9	0.420	8.86@	14.5
0.800	I	99999.898	4.01@	7.7	0.420	9.06@	15.5
0.900	J	99999.898	4.18@	8.3	0.420	9.26@	16.3
Line_End	K	99999.898	2.85@	21.9	0.420	8.16@	30.7
Remote_Bus	L	99999.898	4.35@	8.8	0.420	9.45@	17.1

Simulation Result for New setting:

```
Study Line:
  From:  Rurichu        14 Bus_66Ruri
    To:  Basochu        15 Bus_66Baso

Curve: 1 Substation: Rurichu
         Relay: REL511_Baso Fdr(New) REL511_V2.3_1A DIST "ZM1_GND" Zone 1

Curve: 2 Substation: Rurichu
         Relay: REL511_Baso Fdr(New) REL511_V2.3_1A DIST "ZM2_GND" Zone 2
```

Fault Location	Fault Code	CURVE 1 OPER. SEC	CURVE 1 APP. IMP	CURVE 2 OPER. SEC	CURVE 2 APP. IMP
Close_in	A	0.020	2.83@ -2.8	0.420	6.83@ 13.5
0.100	B	0.020	2.96@ -0.9	0.420	7.05@ 15.3
0.200	C	0.020	3.10@ 0.9	0.420	7.26@ 16.9
0.300	D	0.020	3.24@ 2.4	0.420	7.48@ 18.3
0.400	E	0.020	3.38@ 3.8	0.420	7.70@ 19.5
0.500	F	0.020	3.53@ 5.0	0.420	7.91@ 20.6
0.600	G	0.020	3.69@ 6.0	0.420	8.12@ 21.6
0.700	H	0.020	3.85@ 6.9	0.420	8.33@ 22.4
0.800	I	0.020	4.01@ 7.7	0.420	8.53@ 23.1
0.900	J	0.020	4.18@ 8.3	0.420	8.72@ 23.7
Line_End	K	99999.898	2.85@ 21.9	99999.898	7.44@ 41.7
Remote_Bus	L	0.020	4.35@ 8.8	0.420	8.91@ 24.2

Simulation Result for Existing setting:

```
Study Line:
  From:  Semtokha       5 Bus_66Semto
    To:  Olakha         10 Bus_66Olakha

Curve: 1 Substation: Semtokha
         Relay: REL511_Sem-Olakha REL511_V2.3_1A DIST "ZM1_GND" Zone 1

Curve: 2 Substation: Semtokha
         Relay: REL511_Sem-Olakha REL511_V2.3_1A DIST "ZM2_GND" Zone 2

Curve: 3 Substation: Semtokha
         Relay: REL511_Sem-Olakha REL511_V2.3_1A DIST "ZM3_GND" Zone 3
```

Fault Location	Fault Code	CURVE 1 OPER. SEC	CURVE 1 APP. IMP	CURVE 2 OPER. SEC	CURVE 2 APP. IMP	CURVE 3 OPER. SEC	CURVE 3 APP. IMP
Close_in	A	99999.898	3.46@ 2.4	0.420	3.42@ 2.0	0.820	3.43@ 2.1
0.100	B	99999.898	3.52@ 4.1	0.420	3.49@ 3.8	0.820	3.50@ 3.9
0.200	C	99999.898	3.59@ 5.9	0.420	3.55@ 5.5	0.820	3.56@ 5.6
0.300	D	99999.898	3.66@ 7.5	0.420	3.62@ 7.2	0.820	3.63@ 7.2
0.400	E	99999.898	3.73@ 9.1	0.420	3.69@ 8.7	0.820	3.70@ 8.8
0.500	F	99999.898	3.80@ 10.6	0.420	3.76@ 10.3	0.820	3.77@ 10.4
0.600	G	99999.898	3.88@ 12.1	0.420	3.83@ 11.7	0.820	3.84@ 11.8
0.700	H	99999.898	3.95@ 13.5	0.420	3.91@ 13.2	0.820	3.92@ 13.2
0.800	I	99999.898	4.03@ 14.8	0.420	3.99@ 14.5	0.820	4.00@ 14.6
0.900	J	99999.898	4.12@ 16.1	0.420	4.07@ 15.8	0.820	4.08@ 15.9
Line_End	K	99999.898	3.67@ 17.1	0.420	3.63@ 16.8	0.820	3.64@ 16.9
Remote_Bus	L	99999.898	4.20@ 17.4	0.420	4.16@ 17.1	0.820	4.17@ 17.1

Simulation Result for New setting:

```
Study Line:
  From:  Semtokha       5 Bus_66Semto
    To:  Olakha         10 Bus_66Olakha

Curve: 1 Substation: Semtokha
         Relay: REL511_Sem-Ola(New) REL511_V2.3_1A DIST "ZM1_GND" Zone 1

Curve: 2 Substation: Semtokha
         Relay: REL511_Sem-Ola(New) REL511_V2.3_1A DIST "ZM2_GND" Zone 2
```

Fault Location	Fault Code	CURVE 1 OPER. SEC	CURVE 1 APP. IMP	CURVE 2 OPER. SEC	CURVE 2 APP. IMP
Close_in	A	0.020	2.29@ -0.1	0.420	2.30@ -0.7
0.100	B	0.020	2.33@ 1.7	0.420	2.34@ 1.0
0.200	C	0.020	2.37@ 3.4	0.420	2.39@ 2.7
0.300	D	0.020	2.42@ 5.0	0.420	2.43@ 4.4
0.400	E	0.020	2.46@ 6.6	0.420	2.48@ 6.0
0.500	F	0.020	2.51@ 8.1	0.420	2.53@ 7.5
0.600	G	0.020	2.56@ 9.6	0.420	2.58@ 9.0
0.700	H	0.020	2.61@ 11.0	0.420	2.63@ 10.4
0.800	I	0.020	2.67@ 12.4	0.420	2.68@ 11.7
0.900	J	99999.898	2.72@ 13.7	0.420	2.74@ 13.0
Line_End	K	99999.898	2.47@ 14.9	0.420	2.49@ 14.3
Remote_Bus	L	99999.898	2.78@ 14.9	0.420	2.80@ 14.3

Simulation result for three Phase fault of 5 ohms fault resistance for existing setting:

```
Study Line:
  From:  Semtokha       5 Bus_66Semto
    To:  Olakha         10 Bus_66Olakha

Curve: 1 Substation: Semtokha
         Relay: REL511_Sem-Olakha REL511_V2.3_1A DIST "ZM1_PH" Zone 1

Curve: 2 Substation: Semtokha
         Relay: REL511_Sem-Olakha REL511_V2.3_1A DIST "ZM2_PH" Zone 2

Curve: 3 Substation: Semtokha
         Relay: REL511_Sem-Olakha REL511_V2.3_1A DIST "ZM3_PH" Zone 3
```

Fault Location	Fault Code	CURVE 1 OPER. SEC	CURVE 1 APP. IMP	CURVE 2 OPER. SEC	CURVE 2 APP. IMP	CURVE 3 OPER. SEC	CURVE 3 APP. IMP
Close_in	A	99999.898	6.28@ 3.3	99999.898	6.28@ 3.3	99999.898	6.28@ 3.3
0.100	B	99999.898	6.33@ 4.0	99999.898	6.33@ 4.0	99999.898	6.33@ 4.0
0.200	C	99999.898	6.38@ 4.6	99999.898	6.38@ 4.6	99999.898	6.38@ 4.6
0.300	D	99999.898	6.44@ 5.2	99999.898	6.44@ 5.2	99999.898	6.44@ 5.2
0.400	E	99999.898	6.49@ 5.9	99999.898	6.49@ 5.9	99999.898	6.49@ 5.9
0.500	F	99999.898	6.55@ 6.5	99999.898	6.55@ 6.5	99999.898	6.55@ 6.5
0.600	G	99999.898	6.60@ 7.1	99999.898	6.60@ 7.1	99999.898	6.60@ 7.1
0.700	H	99999.898	6.66@ 7.6	99999.898	6.66@ 7.6	99999.898	6.66@ 7.6
0.800	I	99999.898	6.72@ 8.2	99999.898	6.72@ 8.2	99999.898	6.72@ 8.2
0.900	J	99999.898	6.78@ 8.8	99999.898	6.78@ 8.8	99999.898	6.78@ 8.8
Line_End	K	99999.898	5.42@ 7.5	99999.898	5.42@ 7.5	0.820	5.42@ 7.5
Remote_Bus	L	99999.898	6.83@ 9.3	99999.898	6.83@ 9.3	99999.898	6.83@ 9.3

Simulation result for three Phase fault of 5 ohms fault resistance for new setting:

```
Study Line:
  From:  Semtokha       5 Bus_66Semto
    To:  Olakha         10 Bus_66Olakha

Curve: 1 Substation: Semtokha
         Relay: REL511_Sem-Ola(New) REL511_V2.3_1A DIST "ZM1_PH" Zone 1

Curve: 2 Substation: Semtokha
         Relay: REL511_Sem-Ola(New) REL511_V2.3_1A DIST "ZM2_PH" Zone 2

------------------------------------------------------------------------
   Fault    Fault -------CURVE  1-------  -------CURVE  2-------
  Location  Code  OPER. SEC     APP. IMP  OPER. SEC     APP. IMP
------------------------------------------------------------------------
  Close_in    A       0.020  3.77@   3.3      0.420  3.77@   3.3
     0.100    B       0.020  3.81@   4.4      0.420  3.81@   4.4
     0.200    C       0.020  3.86@   5.4      0.420  3.86@   5.4
     0.300    D       0.020  3.91@   6.5      0.420  3.91@   6.5
     0.400    E       0.020  3.96@   7.5      0.420  3.96@   7.5
     0.500    F       0.020  4.01@   8.4      0.420  4.01@   8.4
     0.600    G       0.020  4.07@   9.4      0.420  4.07@   9.4
     0.700    H   99999.898  4.12@  10.3      0.420  4.12@  10.3
     0.800    I   99999.898  4.18@  11.2      0.420  4.18@  11.2
     0.900    J   99999.898  4.23@  12.1      0.420  4.23@  12.1
  Line_End    K   99999.898  3.44@  11.9      0.420  3.44@  11.9
Remote_Bus    L   99999.898  4.29@  12.9      0.420  4.29@  12.9
------------------------------------------------------------------------
```

APPENDIX [D]: Simulation result for Coordination & Sequential Operation of distance relay:

Creating a SL fault between the 66kV line Jemina- Chumdo at 50% of the protective line and assuming the fault resistance of 5 ohms. The simulation result is as below:

SS_FAULT_COMMAND: APPLY_SILENT_FAULT SLG_A_R5 NEWBUS1

```
**************************************************************
Check_By Simulation: open breakers in successive steps Simulation Area:
```

***** Starting event # 1**

```
Fault 1 of 1:
Midline node on "6 Bus_66Chum"  to  "9 Bus_66Jemina" Ckt 1
"999001 Bus_66Chum" (NEWBUS1) distant 0.500 from "6 Bus_66Chum"
SLG_A_R5 at temporary bus "999001 Bus_66Chum" (NEWBUS1)

Number of fault buses: 1
Bus & phase pair   Fault current Amps @ deg
999001A -      00    1338.345 @  -77.30
```

LZOP Summary Report

```
-------------------
LZOP Operating Times (s) predicted at   0.080 seconds from start:

S/S ID   LZOP        Name     Type P/B Trip LZOP  Breaker  Total
-------------------- ------------------------------ ---- --------------
Olakha 45 66kVOlakha-Jemina LINE Bkp  Z1 0.020 0.060 0.080 Op in event1 3ph

Jemina 48 66kVChumdo feeder LINE Pri  Z1 0.030 0.060 0.090 Bkr opening:3ph

Chumdo 49 66kVJemina feeder LINE Pri  Z1G 0.040 0.060 0.100 Bkr opening:3ph

Chukha 51 66kV Chumdo feeder LINE Bkp  Z3 0.820 0.060 0.880 Predicted


LZOP        Breaker type & location          Bkr opening cyc    Tripped by
-------------------------------------------------------------------------
45 LINE Branch"10Bus_66Olakha"to"9Bus_66Jemina"Ckt1 3.0 Opened 3pole  21OLD

48 LINE Branch"9Bus_66Jemina"to"6Bus_66Chum"Ckt1 3.0  Opening  3pole  21OLD

49 Branch"6Bus_66Chum"to"9Bus_66Jemina"Ckt1 3.0  Opening 3pole 21_TRIP_OLD
```

Network changes now in effect:

```
Midline node on "6 Bus_66Chum"  to  "9 Bus_66Jemina" Ckt 1
"999001 Bus_66Chum" (NEWBUS1) distant 0.500 from "6 Bus_66Chum"
Open breaker on  "10 Bus_66Olakha"  to  "9 Bus_66Jemina" Ckt 1
at "10 Bus_66Olakha"; New bus "999002 Bus_66Olakha" (NEWBUS2)
SLG_A_R5 at temporary bus "999001 Bus_66Chum" (NEWBUS1)
```

Fault is not cleared after   4.0 cycles   0.080 seconds

***** Starting event # 2**

Fault 1 of 1:
Number of fault buses: 1
Bus & phase pair   Fault current Amps @ deg
999001A -   00   582.088 @ -84.25

With breakers open in event # 1 continue to event # 2

Network changes now in effect:
Midline node on "6 Bus_66Chum" to "9 Bus_66Jemina" Ckt 1
"999001 Bus_66Chum" (NEWBUS1) distant 0.500 from "6 Bus_66Chum"
Open breaker on "10 Bus_66Olakha" to "9 Bus_66Jemina" Ckt 1
at "10 Bus_66Olakha"; New bus "999002 Bus_66Olakha" (NEWBUS2)
SLG_A_R5 at temporary bus "999001 Bus_66Chum" (NEWBUS1)

After event 2   4.5 c 0.090 s

LZOP Summary Report

LZOP Operating Times (s) predicted at   0.090 seconds from start:

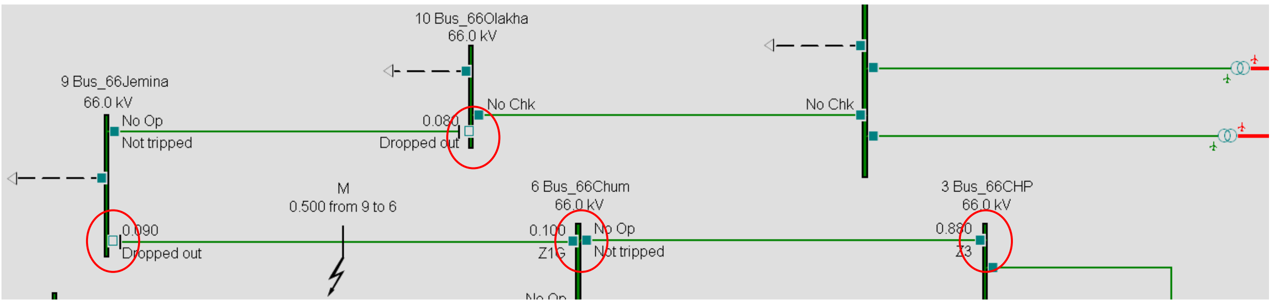
S/S	ID	LZOP Name	Type	P/B	Trip	LZOP	Breaker	Total
Olakha	45	66kV Olakha-Jemina	LINE	Bkp	Z1	0.020	0.060	0.080 Op in event1 3ph
Jemina	48	66kVChumdo feeder	LINE	Pri	Z1	0.030	0.060	0.090 Op in event2 3ph
Chumdo	49	66kV Jemina fdr.	LINE	Pri	Z1G	0.040	0.060	0.100 Bkr opening: 3ph
Chukha	51	66kV Chumdo fdr.	LINE	Bkp	Z3	0.820	0.060	0.880 Predicted

Logical breakers for all LZOPS asserted in previous steps:

LZOP	Breaker type & location	Bkr opening cyc			Tripped by
45	Branch"10Bus_66Olakha"to"9Bus_66Jemina"Ckt1	3.0	Opened	3pole	21OLD
48	Branch"9Bus_66Jemina"to"6Bus_66Chum"Ckt1	3.0	Opened	3pole	21OLD
49	Branch"6Bus_66Chum"to"9Bus_66Jemina"Ckt1	3.0	Opening	3pole	21_TRIP_OLD

Network changes now in effect:
Midline node on "6 Bus_66Chum" to "9 Bus_66Jemina" Ckt 1
"999001 Bus_66Chum" (NEWBUS1) distant 0.500 from "6 Bus_66Chum"
Open breaker on "10 Bus_66Olakha" to "9 Bus_66Jemina" Ckt 1
at "10 Bus_66Olakha"; New bus "999002 Bus_66Olakha" (NEWBUS2)
Open breaker on "9 Bus_66Jemina" to "6 Bus_66Chum" Ckt 1
at "9 Bus_66Jemina"; New bus "999003 Bus_66Jemina" (NEWBUS3)
SLG_A_R5 at temporary bus "999001 Bus_66Chum" (NEWBUS1)

Fault is not cleared after   4.5 cycles   0.090 seconds
Network after Events 2:



```
*** Starting event # 3
Fault 1 of 1:
Bus & phase pair   Fault current Amps @ deg
999001A -      00     586.254 @  -83.75

With breakers open in event # 2 continue to event # 3
-----------------------------------------------------
Network changes now in effect:

Midline node on "6 Bus_66Chum"  to  "9 Bus_66Jemina" Ckt 1
"999001 Bus_66Chum" (NEWBUS1) distant 0.500 from "6 Bus_66Chum"
Open breaker on  "10 Bus_66Olakha"  to  "9 Bus_66Jemina" Ckt 1
at "10 Bus_66Olakha"; New bus "999002 Bus_66Olakha" (NEWBUS2)
Open breaker on  "9 Bus_66Jemina"  to  "6 Bus_66Chum" Ckt 1
at "9 Bus_66Jemina"; New bus "999003 Bus_66Jemina" (NEWBUS3)
SLG_A_R5 at temporary bus "999001 Bus_66Chum" (NEWBUS1)

After event 3   5.0 c 0.100 s

LZOP Summary Report
-------------------
LZOP Operating Times (s) predicted at   0.100 seconds from start:

S/S ID    LZOP       Name    Type P/B Trip    LZOP   Breaker  Total
-------------------- ------------------------------ ---- ---- -------------
Olakha 45 66kVOlakha-Jemina LINE Bkp Z1 0.020 0.060  0.080 Op in event1 3ph

Jemina 48 66kV Chumdo fdr.  LINE Pri Z1 0.030 0.060  0.090 Op in event2 3ph

Chumdo 49 66kV Jemina fdr. LINE Pri Z1G 0.040 0.060  0.100 Op in event3 3ph

Chukha 51 66kV Chumdo fdr. LINE Bkp Z3  0.820 0.060  0.880 Predicted

Logical breakers for all LZOPS asserted in previous steps:
LZOP          Breaker type & location               Bkr opening cyc    Tripped by
---------------------------------------------------------------------------
45 Branch"10Bus_66Olakha"to"9Bus_66Jemina"Ckt1 3.0 Opened   3pole   21OLD

48 Branch"9Bus_66Jemina"to"6Bus_66Chum"Ckt1    3.0 Opened   3pole   21OLD

49 Branch"6Bus_66Chum"to"9Bus_66Jemina"Ckt1  3.0 Opened   3pole   21_TRIP_OLD

Network changes now in effect:
Midline node on "6 Bus_66Chum"  to  "9 Bus_66Jemina" Ckt 1
"999001 Bus_66Chum" (NEWBUS1) distant 0.500 from "6 Bus_66Chum"
Open breaker on  "10 Bus_66Olakha"  to  "9 Bus_66Jemina" Ckt 1
at "10 Bus_66Olakha"; New bus "999002 Bus_66Olakha" (NEWBUS2)
Open breaker on  "9 Bus_66Jemina"  to  "6 Bus_66Chum" Ckt 1
at "9 Bus_66Jemina"; New bus "999003 Bus_66Jemina" (NEWBUS3)
Open breaker on  "6 Bus_66Chum"  to  "9 Bus_66Jemina" Ckt 1
at "6 Bus_66Chum"; New bus "999004 Bus_66Chum" (NEWBUS4)
SLG_A_R5 at temporary bus "999001 Bus_66Chum" (NEWBUS1)

Fault is cleared after    5.0 cycles   0.100 seconds
```

Simulation results for new settings:(66kVChumdo feeder)

SS_FAULT_COMMAND: APPLY_SILENT_FAULT SLG_A_R5 NEWBUS1

```
************************************************************************
```

***** Starting event # 1**

Fault 1 of 1:

```
Midline node on "6 Bus_66Chum"  to  "9 Bus_66Jemina" Ckt 1
"999001 Bus_66Chum" (NEWBUS1) distant 0.500 from "6 Bus_66Chum"
SLG_A_R5 at temporary bus "999001 Bus_66Chum" (NEWBUS1)

Number of fault buses: 1
Bus & phase pair   Fault current Amps @ deg
999001A -    00              1338.345 @  -77.30

Check_By Simulation: open breakers in successive steps Simulation Area:
```

LZOP Summary Report

LZOP Operating Times (s) predicted at 0.090 seconds from start:

S/S ID	LZOP	Name	Type	P/B	Trip	LZOP	Breaker	Total
Jemina	48	66kV Chumdo	LINE	Pri	Z1N	0.030	0.060	0.090 Op in event1 3ph
Chumdo	49	66kV Jemina	LINE	Pri	Z1G	0.040	0.060	0.100 Bkr opening:3ph
Chukha	51	66kV Chumdo	LINE	Bkp	Z3	0.820	0.060	0.880 Predicted
Olakha	45	66kV Olakha	LINE	Bkp	Z3N	0.820	0.060	0.880 Predicted

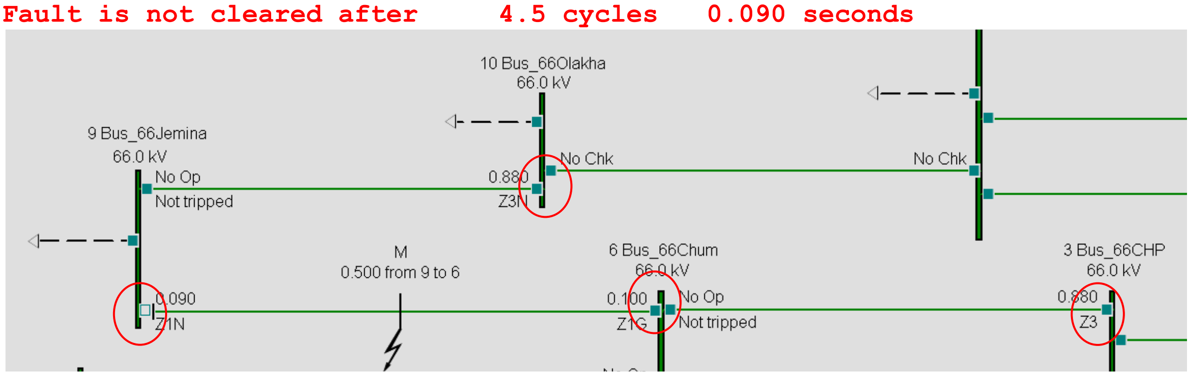
Logical breakers for all LZOPS asserted in this step:

LZOP	Breaker type & location	Bkr opening cyc		Tripped by
48	Branch"9Bus_66Jemina"to"6Bus_66Chum"Ckt1	3.0	Opened 3-pole	21NEW
49	Branch"6Bus_66Chum"to"9Bus_66Jemina"Ckt1	3.0	Opening 3pole	21_TRIP_OLD

Network changes now in effect:

```
Midline node on "6 Bus_66Chum"  to  "9 Bus_66Jemina" Ckt 1
"999001 Bus_66Chum" (NEWBUS1) distant 0.500 from "6 Bus_66Chum"
Open breaker on  "9 Bus_66Jemina"  to  "6 Bus_66Chum" Ckt 1
at "9 Bus_66Jemina"; New bus "999002 Bus_66Jemina" (NEWBUS2)
SLG_A_R5 at temporary bus "999001 Bus_66Chum" (NEWBUS1)
```

Fault is not cleared after 4.5 cycles 0.090 seconds



***** Starting event # 2**

Fault 1 of 1:
Midline node on "6 Bus_66Chum" to "9 Bus_66Jemina" Ckt 1
"999001 Bus_66Chum" (NEWBUS1) distant 0.500 from "6 Bus_66Chum"
Open breaker on "9 Bus_66Jemina" to "6 Bus_66Chum" Ckt 1
at "9 Bus_66Jemina"; New bus "999002 Bus_66Jemina" (NEWBUS2)
SLG_A_R5 at temporary bus "999001 Bus_66Chum" (NEWBUS1)

Number of fault buses: 1
Bus & phase pair Fault current Amps @ deg
999001A - 00 586.175 @ -83.77

With breakers open in event # 1 continue to event # 2

After event 2 5.0 c 0.100 s

LZOP Summary Report

LZOP Operating Times (s) predicted at 0.100 seconds from start:

S/S ID	LZOP	Name	Type P/B Trip	LZOP	Breaker	Total	
Jemina	48	66kV Chumdo	LINE Pri Z1N	0.030	0.060	0.090	Op in event 1 3-ph
Chumdo	49	66kV Jemina	LINE Pri Z1G	0.040	0.060	0.100	Op in event 2 3-ph
Chukha	51	66kV Chumdo	LINE Bkp Z3	0.820	0.060	0.880	Predicted

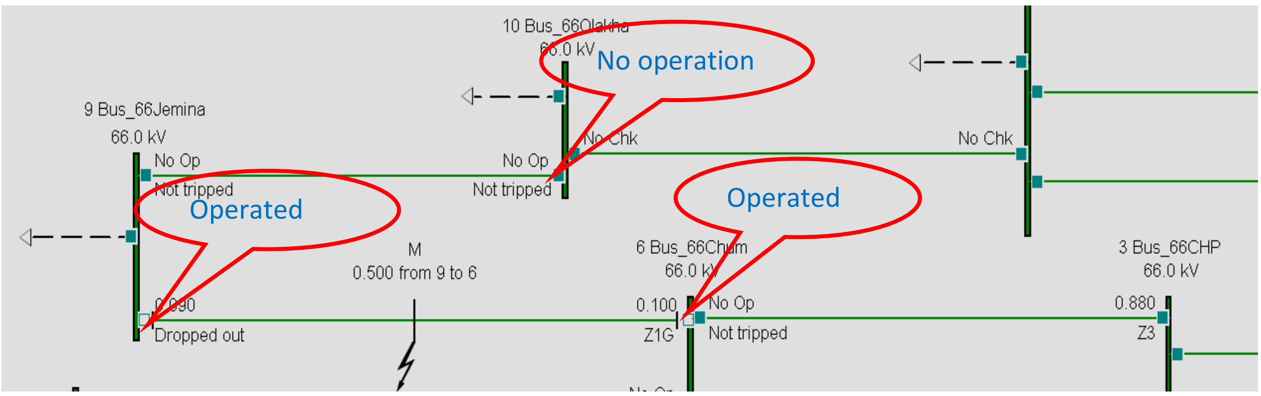
LZOP	Breaker type & location	Bkr opening cyc			Tripped by
48	Branch"9Bus_66Jemina"to"6Bus_66Chum"Ckt1	3.0	Opened	3-pole	21NEW
49	Branch"6Bus_66Chum"to"9Bus_66Jemina"Ckt1	3.0	Opened	3pole	21_TRIP_OLD

Network changes now in effect:

Midline node on "6 Bus_66Chum" to "9 Bus_66Jemina" Ckt 1
"999001 Bus_66Chum" (NEWBUS1) distant 0.500 from "6 Bus_66Chum"
Open breaker on "9 Bus_66Jemina" to "6 Bus_66Chum" Ckt 1
at "9 Bus_66Jemina"; New bus "999002 Bus_66Jemina" (NEWBUS2)
Open breaker on "6 Bus_66Chum" to "9 Bus_66Jemina" Ckt 1
at "6 Bus_66Chum"; New bus "999003 Bus_66Chum" (NEWBUS3)
SLG_A_R5 at temporary bus "999001 Bus_66Chum" (NEWBUS1)

Fault is cleared after 5.0 cycles 0.100 seconds

Final Network after fault is cleared and showing the relay operation:

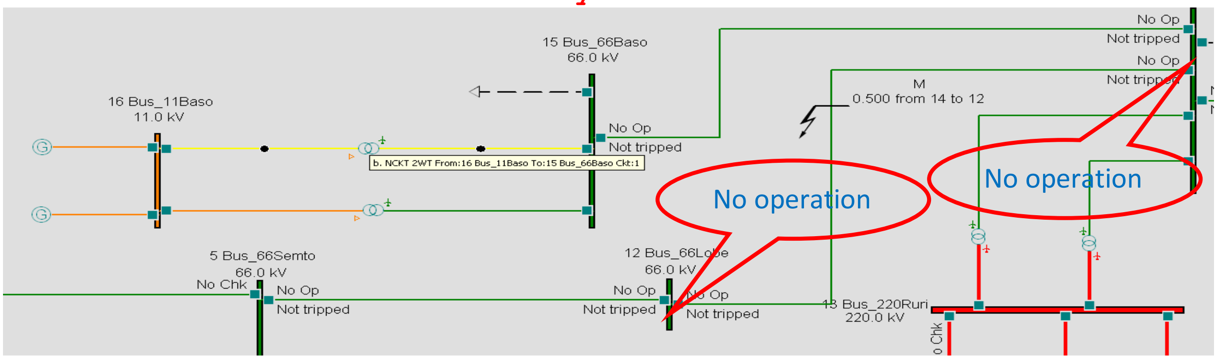


APPENDIX [E]: Simulation showing the important of 67N:

Case1: Simulation Result for without 67N:

```
SS_FAULT_COMMAND: APPLY_SILENT_FAULT SLG_A_R20 NEWBUS1
*****************************************************************
*** Starting event # 1
Fault 1 of 1:
Midline node on "12 Bus_66Lobe"  to  "14 Bus_66Ruri" Ckt 1
"999001 Bus_66Lobe" (NEWBUS1) distant 0.500 from "12 Bus_66Lobe"
SLG_A_R20 at temporary bus "999001 Bus_66Lobe" (NEWBUS1)

Bus & phase pair   Fault current Amps @ deg
999001A -   00            1325.622 @  -43.94

Check_By Simulation: open breakers in successive steps Simulation Area:
```

Fault is not cleared after 1.0 cycles 0.020 seconds



From above simulation we see that all the distance relay were not detecting the high impedance fault, therefore it is not operated and the fault is not able to clear.

Case2: Simulation Result for with 67N:

```
SS_FAULT_COMMAND: APPLY_SILENT_FAULT SLG_A_R20 NEWBUS1
****************************************************************************
*** Starting event # 1
Fault 1 of 1:
Midline node on "12 Bus_66Lobe"  to  "14 Bus_66Ruri" Ckt 1
"999001 Bus_66Lobe" (NEWBUS1) distant 0.500 from "12 Bus_66Lobe"
SLG_A_R20 at temporary bus "999001 Bus_66Lobe" (NEWBUS1)

Number of fault buses: 1
Bus & phase pair   Fault current Amps @ deg
999001A -      00    1325.622 @  -43.94

Check_By Simulation: open breakers in successive steps

After event 1  21.7 c 0.434 s
```

Fastest Primary:

```
Primary LZOP:    28 66kV Rurichu-Lobeysa feeder at Rurichu; 3-pole
LZOP 0.374; Breaker 0.060; LZOP+Bkr 0.434  sec

Trip path    TEF  REL511_Lobeysa Fdr.  28 TOC   IN>_TEF   0.374 sec from
start
```

Fastest Backup:

```
Backup LZOP:    43 66kV Semtokha-Lobeysa feeder at Semtokha; 3-pole
LZOP  1.04; Breaker 0.060; LZOP+Bkr  1.10  sec
```

Trip path   TEF REL511_Sem-Lobeysa 46 TOC   IN>_TEF 1.042 sec from start

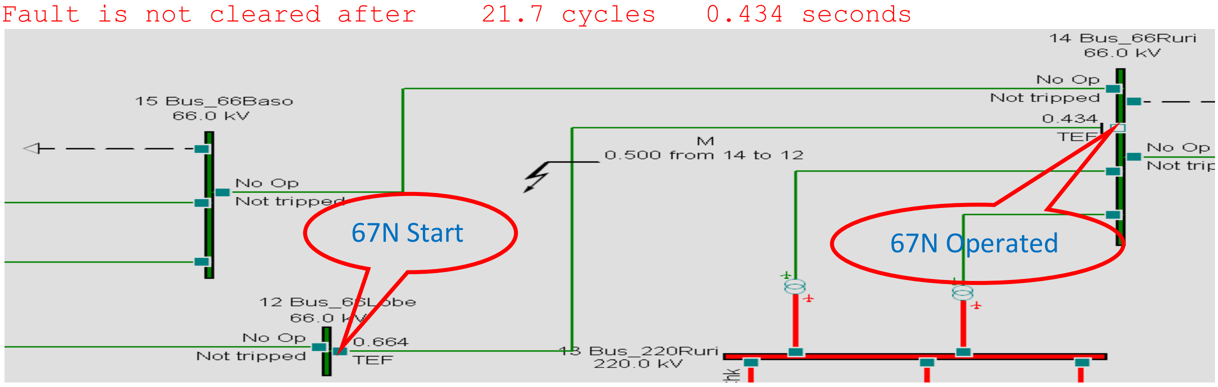
CTI: Min desired 0.300   Max desired 9999.00   Predicted   0.668 seconds
CTI Defn: TB_LZOP - TP_LZOP

LZOP Summary Report
S/S ID   LZOP   Name   Type P/B Trip LZOP Breaker Total
-------------------- ------------------------------ ---- ---- -------------
Rurichu 28 66kV Rurichu LINE Pri TEF 0.374   0.060 0.434 Op in event1 3ph

Lobeysa 41 66kV Lobeysa LINE Pri TEF 0.604   0.060 0.664 Predicted

Semtokha 43 66kV Semtokha LINE Bkp TEF 1.042 0.060 1.102 Predicted
----
LZOP   Breaker type & location   Bkr opening cyc   Tripped by
----
28 Branch"14Bus_66Ruri-12Bus_66Lobe"Ckt1 3.0Opened 3pole GENTRIPNEW_ABB

Network changes now in effect:
Midline node on "12 Bus_66Lobe" to "14 Bus_66Ruri" Ckt 1
"999001 Bus_66Lobe" (NEWBUS1) distant 0.500 from "12 Bus_66Lobe"
Open breaker on "14 Bus_66Ruri" to "12 Bus_66Lobe" Ckt 1
at "14 Bus_66Ruri"; New bus "999002 Bus_66Ruri" (NEWBUS2)
SLG_A_R20 at temporary bus "999001 Bus_66Lobe" (NEWBUS1)
Fault is not cleared after   21.7 cycles   0.434 seconds



***** Starting event # 2**
Fault 1 of 1:
Number of fault buses: 1
Bus & phase pair   Fault current Amps @ deg
999001A -   00   572.147 @ -70.82

With breakers open in event # 1 continue to event # 2

Network changes now in effect:

Midline node on "12 Bus_66Lobe" to "14 Bus_66Ruri" Ckt 1
"999001 Bus_66Lobe" (NEWBUS1) distant 0.500 from "12 Bus_66Lobe"
Open breaker on "14 Bus_66Ruri" to "12 Bus_66Lobe" Ckt 1
at "14 Bus_66Ruri"; New bus "999002 Bus_66Ruri" (NEWBUS2)
SLG_A_R20 at temporary bus "999001 Bus_66Lobe" (NEWBUS1)

After event 2 25.7 c 0.514 s

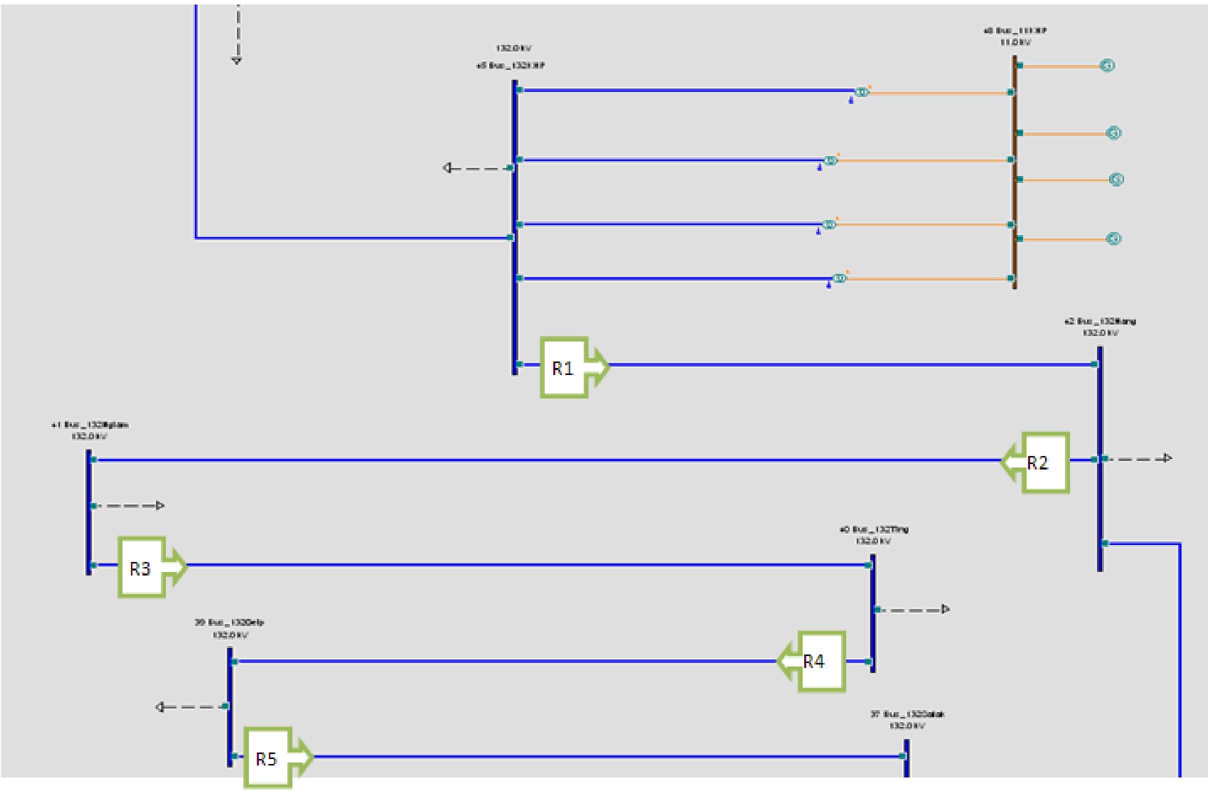
Fastest Primary:
Primary LZOP: 41 66kV Lobeysa-Basochu feeder at Lobeysa; 3-pole
LZOP 0.454; Breaker 0.060; LZOP+Bkr 0.514 sec
Trip path   Z1G_N REL511_Lob-Ruri(New) 73 DIST ZM1_GND   1 0.454 sec
from start

```
Fastest Backup:
Backup LZOP:    43 66kV Semtokha-Lobeysa feeder at Semtokha; 3-pole
LZOP 0.854; Breaker 0.060; LZOP+Bkr 0.914  sec
Trip path    Z2G  REL511_Sem-Lobeysa   46 TIMER t2PE   1  0.854 sec from
start

CTI: Min desired  0.300   Max desired  9999.00   Predicted   0.400 seconds
CTI Defn: TB_LZOP - TP_LZOP


LZOP Summary Report
------------------
S/S ID    LZOP    Name    Type  P/B Trip LZOP  Breaker  Total
-------------------- ------------------------------ ---- ---- -------------
Rurichu 28 66kV Rurichu-Lobeysa Pri TEF 0.374  0.060 0.434 Op in event1 3ph

Lobeysa 41 66kV Lobeysa-Basochu Pri Z1G_N 0.454 0.060 0.514 Op event2 3ph

Semtokha 43 66kV Semtokha-Lobeysa Bkp Z2G 0.854  0.060  0.914 Predicted
---------------------------------------------------------------------------

LZOP        Breaker type & location                Bkr opening cyc
Tripped by
---------------------------------------------------------------------------
28LINE Branch"14Bus_66Ruri-12Bus_66Lobe"Ckt13.0 Opened3-pole GENTRIPNEW_ABB

41LINE Branch"12Bus_66Lobe-14Bus_66Ruri"Ckt13.0 Opened3-pole GENTRIPNEW_ABB

Network changes now in effect:
Midline node on "12 Bus_66Lobe"  to  "14 Bus_66Ruri" Ckt 1
"999001 Bus_66Lobe" (NEWBUS1) distant 0.500 from "12 Bus_66Lobe"
Open breaker on  "14 Bus_66Ruri"  to  "12 Bus_66Lobe" Ckt 1
at "14 Bus_66Ruri"; New bus "999002 Bus_66Ruri" (NEWBUS2)
Open breaker on  "12 Bus_66Lobe"  to  "14 Bus_66Ruri" Ckt 1
at "12 Bus_66Lobe"; New bus "999003 Bus_66Lobe" (NEWBUS3)
SLG_A_R20 at temporary bus "999001 Bus_66Lobe" (NEWBUS1)

Fault is cleared after   25.7 cycles   0.514 seconds
```

APPENDIX [F]: Simulation Result 67N (CDD21) Coordination:

132kV line between Kurichu to Gelephu, Relay coordination checking for the relay looking towards the Gelephu:

Case 1: Existing setting simulation result:



Fault: A

SLG_A_R30 at temporary bus 999001 Bus_132Gelp (NEWBUS1)
Midline node on "39 Bus_132Gelp" to "37 Bus_132Salak" Ckt 1
"999001 Bus_132Gelp" (NEWBUS1) distant **0.500 from "39 Bus_132Gelp"**

Curve	Current Primary A	Current A/Pickup	Operating Seconds	Source/Total line (+ seq SIR)
1	183.64	1.84	4.526	3.24 @ 21.5
2	231.89	3.86	1.404	2.67 @ 14.0
3	231.89	3.86	1.022	1.51 @ 10.7
4	231.89	3.86	0.766	4.63 @ 5.9
5	231.89	3.86	0.510	5.01 @ 4.9

Fault: B

SLG_A_R30 at temporary bus 999001 Bus_132Gelp (NEWBUS1)
Midline node on "39 Bus_132Gelp" to "40 Bus_132Ting" Ckt 1
"999001 Bus_132Gelp" (NEWBUS1) distant **0.499 from "39 Bus_132Gelp"**

Curve	Current Primary A	Current A/Pickup	Operating Seconds	Source/Total line (+ seq SIR)
1	273.84	2.74	2.720	3.24 @ 21.5
2	381.21	6.35	1.022	2.45 @ 14.3
3	381.21	6.35	0.744	1.42 @ 10.7
4	381.21	6.35	0.558	4.46 @ 5.7
5	781.25	13.02	Infinite	1.70 @-171.7

Fault: C

SLG_A_R30 at temporary bus 999001 Bus_132Ting (NEWBUS1)
Midline node on "40 Bus_132Ting" to "41 Bus_132Nglam" Ckt 1
"999001 Bus_132Ting" (NEWBUS1) distant **0.500 from "40 Bus_132Ting"**

Curve	**Current Primary A**	**Current A/Pickup**	**Operating Seconds**	**Source/Total line (+ seq SIR)**
1	428.79	4.29	1.874	3.24 @ 21.5
2	618.83	10.31	0.806	2.35 @ 14.1
3	618.83	10.31	0.586	1.38 @ 10.5
4	454.34	7.57	Infinite	2.95 @-174.4
5	454.34	7.57	Infinite	1.74 @-171.5

Fault: D

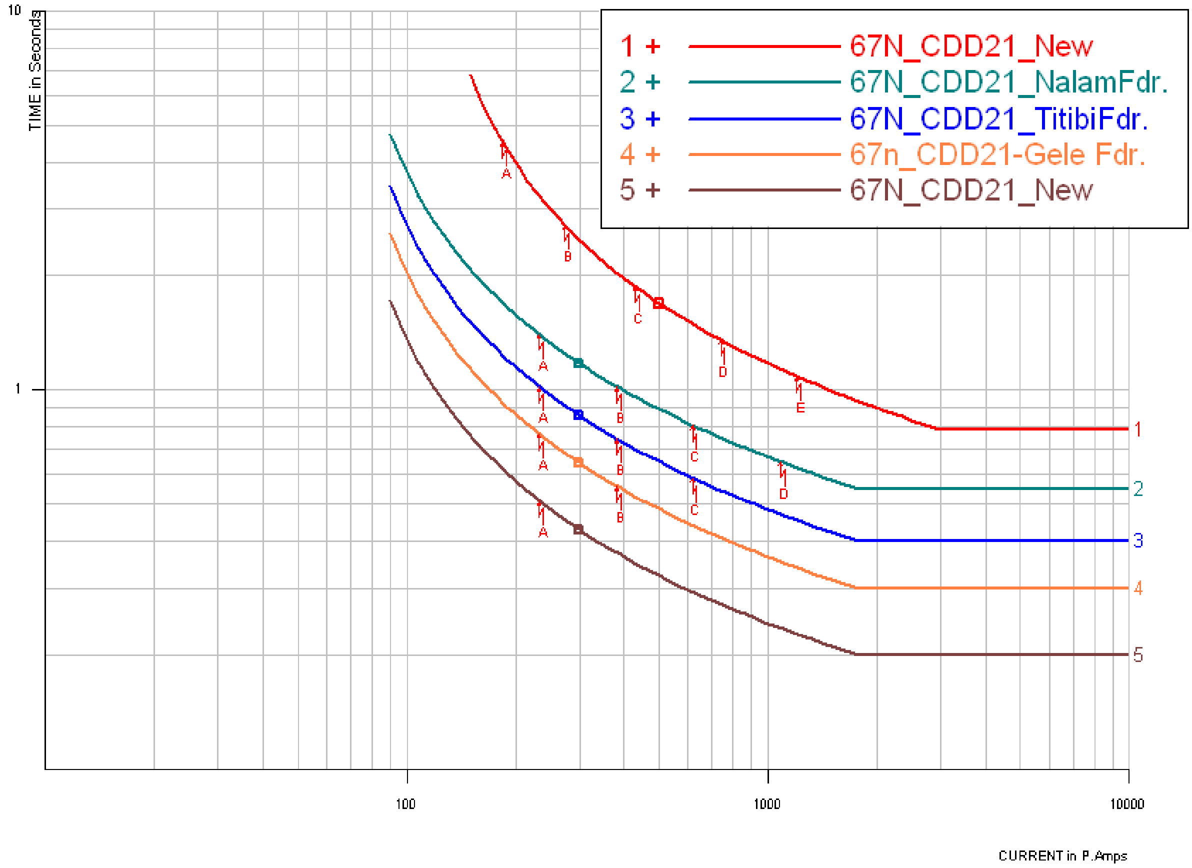
SLG_A_R30 at temporary bus 999001 Bus_132Nglam (NEWBUS1)
Midline node on "41 Bus_132Nglam" to "42 Bus_132Nang" Ckt 1
"999001 Bus_132Nglam" (NEWBUS1) distant **0.500 from "41 Bus_132Nglam"**

Curve	**Current Primary A**	**Current A/Pickup**	**Operating Seconds**	**Source/Total line (+ seq SIR)**
1	739.98	7.40	1.356	3.24 @ 21.5
2	1082.77	18.05	0.646	2.31 @ 14.0
3	262.21	4.37	Infinite	2.63 @-176.1
4	262.21	4.37	Infinite	3.03 @-174.3
5	262.21	4.37	Infinite	1.82 @-171.4

Fault: E

SLG_A_R30 at temporary bus 999001 Bus_132Nang (NEWBUS1)
Midline node on "42 Bus_132Nang" to "45 Bus_132KHP" Ckt 1
"999001 Bus_132Nang" (NEWBUS1) distant **0.501 from "42 Bus_132Nang"**

Curve	**Current Primary A**	**Current A/Pickup**	**Operating Seconds**	**Source/Total line (+ seq SIR)**
1	1197.90	11.98	1.088	3.24 @ 21.5
2	136.28	2.27	Infinite	7.44 @-177.1
3	136.28	2.27	Infinite	2.66 @-176.1
4	136.28	2.27	Infinite	3.08 @-174.3
5	136.28	2.27	Infinite	1.86 @-171.6



From the above simulation the operation sequence are fine but operating time of the relay is longer than Zone 2 timing for all the cases. Therefore time coordination is required.

Case 2: New setting simulation result:

Fault: A

SLG_A_R30 at temporary bus 999001 Bus_132Gelp (NEWBUS1)
Midline node on "39 Bus_132Gelp" to "37 Bus_132Salak" Ckt 1
"999001 Bus_132Gelp" (NEWBUS1) distant **0.500 from "39 Bus_132Gelp"**

Curve	Current Primary A	A/Pickup	Operating Seconds	Source/Total line (+ seq SIR)
1	183.64	1.84	2.562	3.24 @ 21.5
2	231.89	3.86	1.016	2.67 @ 14.0
3	231.89	3.86	0.838	1.51 @ 10.7
4	231.89	3.86	0.658	4.63 @ 5.9
5	231.89	3.86	0.510	5.01 @ 4.9

Fault: B

SLG_A_R30 at temporary bus 999001 Bus_132Gelp (NEWBUS1)
Midline node on "39 Bus_132Gelp" to "40 Bus_132Ting" Ckt 1
"999001 Bus_132Gelp" (NEWBUS1) distant **0.499 from "39 Bus_132Gelp"**

Curve	Current Primary A	A/Pickup	Operating Seconds	Source/Total line (+ seq SIR)
1	273.84	2.74	1.540	3.24 @ 21.5
2	381.21	6.35	0.740	2.45 @ 14.3
3	381.21	6.35	0.610	1.42 @ 10.7
4	381.21	6.35	0.480	4.46 @ 5.7
5	781.25	13.02	Infinite	1.70 @-171.7

Fault: C

SLG_A_R30 at temporary bus 999001 Bus_132Ting (NEWBUS1)
Midline node on "40 Bus_132Ting" to "41 Bus_132Nglam" Ckt 1
"999001 Bus_132Ting" (NEWBUS1) distant 0.500 from "40 Bus_132Ting"

Curve	Current Primary A	A/Pickup	Operating Seconds	Source/Total line (+ seq SIR)
1	428.79	4.29	1.060	3.24 @ 21.5
2	618.83	10.31	0.584	2.35 @ 14.1
3	618.83	10.31	0.480	1.38 @ 10.5
4	454.34	7.57	Infinite	2.95 @-174.4
5	454.34	7.57	Infinite	1.74 @-171.5

Fault: D

SLG_A_R30 at temporary bus 999001 Bus_132Nglam (NEWBUS1)
Midline node on "41 Bus_132Nglam" to "42 Bus_132Nang" Ckt 1
"999001 Bus_132Nglam" (NEWBUS1) distant **0.500 from "41 Bus_132Nglam"**

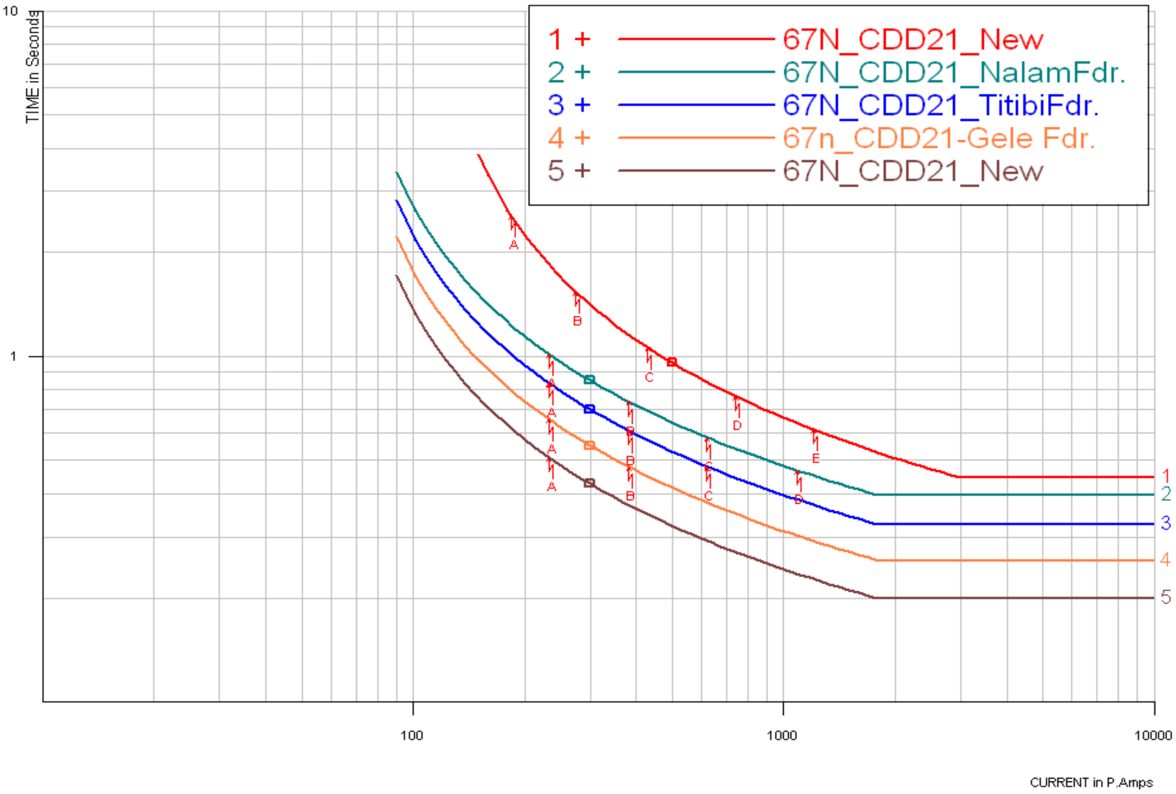
Curve	Current Primary A	A/Pickup	Operating Seconds	Source/Total line (+ seq SIR)
1	739.98	7.40	0.768	3.24 @ 21.5
2	1082.77	18.05	0.468	2.31 @ 14.0
3	262.21	4.37	Infinite	2.63 @-176.1
4	262.21	4.37	Infinite	3.03 @-174.3
5	262.21	4.37	Infinite	1.82 @-171.4

Fault: E

SLG_A_R30 at temporary bus 999001 Bus_132Nang (NEWBUS1)
Midline node on "42 Bus_132Nang" to "45 Bus_132KHP" Ckt 1
"999001 Bus_132Nang" (NEWBUS1) distant 0.501 from "42 Bus_132Nang"

Curve	Current Primary A	A/Pickup	Operating Seconds	Source/Total line (+ seq SIR)
1	1197.90	11.98	0.616	3.24 @ 21.5
2	136.28	2.27	Infinite	7.44 @-177.1
3	136.28	2.27	Infinite	2.66 @-176.1
4	136.28	2.27	Infinite	3.08 @-174.3
5	136.28	2.27	Infinite	1.86 @-171.6

Coordination curve for new setting:



220kV feeders, 67N coordination of REL 511 simulation result:

Existing Setting:

```
 Fault: A
SINGLE_LINE_GROUND at temporary bus 999001 Bus_220Semto (NEWBUS1)
Midline node on "4 Bus_220Semto"  to  "13 Bus_220Ruri" Ckt 1
"999001 Bus_220Semto" (NEWBUS1) distant 0.951 from "4 Bus_220Semto"

 Curve            Current          Operating   Source/Total line (+ seq SIR)
        Primary A  A/Pickup        Seconds
 ______________________________________________________________________________

   1       1318.50     17.58         0.260      2.64 @   3.1
   2       1293.31     10.78         0.374      0.72 @   7.8
   3        200.50      1.25         4.642      3.43 @ 10.1


 Fault: B
SINGLE_LINE_GROUND at temporary bus 999001 Bus_220Semto (NEWBUS1)
Midline node on "4 Bus_220Semto"  to  "13 Bus_220Ruri" Ckt 1
"999001 Bus_220Semto" (NEWBUS1) distant 0.066 from "4 Bus_220Semto"

 Curve            Current          Operating   Source/Total line (+ seq SIR)
        Primary A  A/Pickup        Seconds
  __________________________________________________________________________
   1       2201.49     29.35         0.220      2.58 @   3.0
   2       2106.03     17.55         0.308      0.71 @   7.7
   3        326.10      2.04         1.464      3.41 @   9.8
```

Fault: C
SINGLE_LINE_GROUND at Midline node on "4 Bus_220Semto" to "2 Bus_220CHP" Ckt 1
"999001 Bus_220Semto" (NEWBUS1) distant **0.074 from "4 Bus_220Semto"**

Curve	Current Primary A	A/Pickup	Operating Seconds	Source/Total line (+ seq SIR)
1	1281.61	17.09	Infinite	13.06 @-171.7
2	2349.92	19.58	0.296	0.71 @ 7.6
3	363.09	2.27	1.270	3.40 @ 9.7

Fault: D
SINGLE_LINE_GROUND at Midline node on "4 Bus_220Semto" to "2 Bus_220CHP" Ckt 1
"999001 Bus_220Semto" (NEWBUS1) distant **0.918 from "4 Bus_220Semto"**

Curve	Current Primary A	A/Pickup	Operating Seconds	Source/Total line (+ seq SIR)
1	672.50	8.97	Infinite	13.58 @-170.4
2	7484.61	62.37	0.256	0.69 @ 7.4
3	1138.50	7.12	0.524	3.30 @ 9.0

Fault: E
SINGLE_LINE_GROUND at temporary bus 999001 Bus_220CHP (NEWBUS1)
Midline node on "2 Bus_220CHP" to "20 Bus_220Malbe" Ckt 1
"999001 Bus_220CHP" (NEWBUS1) distant **0.052 from "2 Bus_220CHP"**

Curve	Current Primary A	A/Pickup	Operating Seconds	Source/Total line (+ seq SIR)
1	515.03	6.87	Infinite	13.72 @-170.1
2	521.57	4.35	Infinite	9.20 @-172.0
3	1578.26	9.86	0.448	3.12 @ 8.9

Fault: F
SINGLE_LINE_GROUND at temporary bus 999001 Bus_220CHP (NEWBUS1)
Midline node on "2 Bus_220CHP" to "20 Bus_220Malbe" Ckt 1
"999001 Bus_220CHP" (NEWBUS1) distant 0.928 from "2 Bus_220CHP"

Curve	Current Primary A	A/Pickup	Operating Seconds	Source/Total line (+ seq SIR)
1	243.14	3.24	Infinite	13.92 @-169.4
2	242.22	2.02	Infinite	9.73 @-170.4
3	4784.30	29.90	0.298	1.90 @ 7.5

New Setting Simulation Result:

Fault: A

SINGLE_LINE_GROUND at temporary bus 999001 Bus_220Semto (NEWBUS1)
Midline node on "4 Bus_220Semto" to "13 Bus_220Ruri" Ckt 1
"999001 Bus_220Semto" (NEWBUS1) distant 0.951 from "4 Bus_220Semto"

Curve	Current Primary A	Current A/Pickup	Operating Seconds	Source/Total line (+ seq SIR)
1	1318.50	21.97	0.220	2.64 @ 3.1
2	1293.31	14.37	0.282	0.72 @ 7.8
3	200.50	1.67	1.628	3.43 @ 10.1
4	1318.50	0.99	Infinite	Unavailable
5	1293.31	0.56	Infinite	Unavailable
6	200.50	0.06	Infinite	Unavailable

Fault: B

SINGLE_LINE_GROUND at temporary bus 999001 Bus_220Semto (NEWBUS1)
Midline node on "4 Bus_220Semto" to "13 Bus_220Ruri" Ckt 1
"999001 Bus_220Semto" (NEWBUS1) distant 0.041 from "4 Bus_220Semto"

Curve	Current Primary A	Current A/Pickup	Operating Seconds	Source/Total line (+ seq SIR)
1	2234.99	37.25	0.196	2.57 @ 3.0
2	2137.06	23.75	0.236	0.71 @ 7.7
3	330.90	2.76	0.820	3.41 @ 9.8
4	2234.99	1.67	0.020	Unavailable
5	2137.06	0.92	Infinite	Unavailable
6	330.90	0.10	Infinite	Unavailable

Fault: C

SINGLE_LINE_GROUND at temporary bus 999001 Bus_220Semto (NEWBUS1)
Midline node on "4 Bus_220Semto" to "2 Bus_220CHP" Ckt 1
"999001 Bus_220Semto" (NEWBUS1) distant 0.058 from "4 Bus_220Semto"

Curve	Current Primary A	Current A/Pickup	Operating Seconds	Source/Total line (+ seq SIR)
1	1291.63	21.53	Infinite	13.06 @-171.7
2	2312.98	25.70	0.230	0.71 @ 7.7
3	357.54	2.98	0.762	3.40 @ 9.7
4	1291.63	0.97	Infinite	Unavailable
5	2312.98	1.00	Infinite	Unavailable
6	357.54	0.11	Infinite	Unavailable

Fault: D

```
SINGLE_LINE_GROUND at temporary bus 999001 Bus_220Semto (NEWBUS1)
Midline node on "4 Bus_220Semto"  to  "2 Bus_220CHP" Ckt 1
"999001 Bus_220Semto" (NEWBUS1) distant 0.947 from "4 Bus_220Semto"

Curve          Current          Operating   Source/Total line (+ seq SIR)
        Primary A  A/Pickup     Seconds
______________________________________________________________________

  1        634.43    10.57     Infinite   13.62 @-170.3
  2       8002.08    88.91        0.216    0.69 @   7.4
  3       1216.77    10.14        0.354    3.30 @   9.0
  4        634.43     0.47     Infinite    Unavailable
  5       8002.08     3.45        0.020    Unavailable
  6       1216.77     0.39     Infinite    Unavailable
```

Fault: E

```
SINGLE_LINE_GROUND at temporary bus 999001 Bus_220CHP (NEWBUS1)
Midline node on "2 Bus_220CHP"  to  "20 Bus_220Malbe" Ckt 1
"999001 Bus_220CHP" (NEWBUS1) distant 0.024 from "2 Bus_220CHP"

Curve          Current          Operating   Source/Total line (+ seq SIR)
        Primary A  A/Pickup     Seconds
______________________________________________________________________

  1        534.31     8.91     Infinite   13.71 @-170.2
  2        541.25     6.01     Infinite    9.19 @-172.1
  3       1481.06    12.34        0.326    3.21 @   8.9
  4        534.31     0.40     Infinite    Unavailable
  5        541.25     0.23     Infinite    Unavailable
  6       1481.06     0.47     Infinite    Unavailable
```

Fault: F

```
SINGLE_LINE_GROUND at temporary bus 999001 Bus_220CHP (NEWBUS1)
Midline node on "2 Bus_220CHP"  to  "20 Bus_220Malbe" Ckt 1
"999001 Bus_220CHP" (NEWBUS1) distant 0.959 from "2 Bus_220CHP"

Curve          Current          Operating   Source/Total line (+ seq SIR)
        Primary A  A/Pickup     Seconds
______________________________________________________________________

  1        239.00     3.98     Infinite   13.93 @-169.3
  2        237.84     2.64     Infinite    9.76 @-170.3
  3       4954.75    41.29        0.236    1.88 @   7.5
  4        239.00     0.18     Infinite    Unavailable
  5        237.84     0.10     Infinite    Unavailable
  6       4954.75     1.57        0.020    Unavailable
```

APPENDIX [G]: Propose relay setting details:

66kV feeders:

Location | Device Remarks

Local Zone of Protection Data

Substation: Chukha
LZOP ID: LINE 10
Name: 66kV Chumdo feeder
LZOP Rank: 1

Change LZOP | View LZOP

Device Tag: 69 | Archived
Relay Tag: 67
Device Name: 7SA612_Chumdo fdr.
Active Group:

<< Advanced

Group Displayed: | Rename | Copy | Delete | Compare | Move

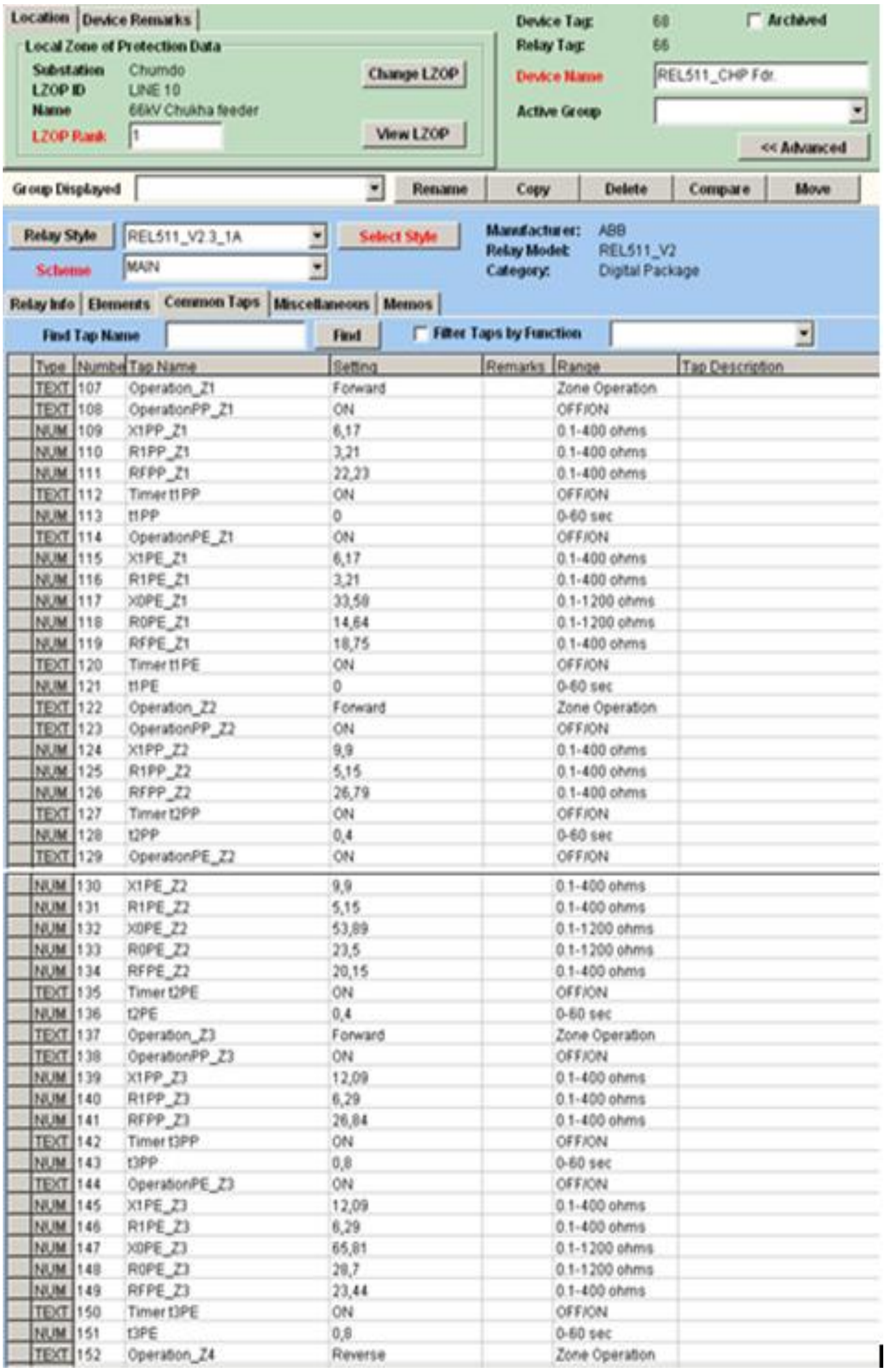
Relay Style: 7SA6xx_V4.3_1A | Select Style
Scheme: MAIN

Manufacturer: SIEMENS
Relay Model: 7SA6
Category: Digital Package

Relay Info | Elements | Common Taps | Miscellaneous | Memos

Find Tap Name: | Find | Filter Taps by Function

Type	Numbe	Tap Name	Setting	Remarks	Range	Tap Description
TEXT	110	1301 Op. mode Z1	Forward		Fwd/Rev/Non/Inacti	
NUM	111	1302 R(Z1) ph-ph	5,71		0.05-600 ohms	
NUM	112	1303 X(Z1)	6,168		0.05-600 ohms	
NUM	113	1304 RE(Z1) ph-E	13,21		0.05-600 ohms	
BOTH	114	1305 T1-1phase	0		0-30 sec	
BOTH	115	1306 T1-multi-phase	0		0-30 sec	
NUM	116	1307 Zone Reduction	0		0-45 deg	
TEXT	117	1311 Op. mode Z2	Forward		Fwd/Rev/Non/Inacti	
NUM	118	1312 R(Z2) ph-ph	7,142		0.05-600 ohms	
NUM	119	1313 X(Z2)	8,92		0.05-600 ohms	
NUM	120	1314 RE(Z2) ph-E	14,642		0.05-600 ohms	
BOTH	121	1315 T2-1phase	0,4		0-30 sec	
BOTH	122	1316 T2-multi-phase	0		0-30 sec	
TEXT	123	1317 Trip 1 pole Z2	NO		NO/YES	
TEXT	124	1321 Op. mode Z3	Forward		Fwd/Rev/Non/Inacti	
NUM	125	1322 R(Z3) ph-ph	10,136		0.05-600 ohms	
NUM	126	1323 X(Z3)	14,674		0.05-600 ohms	
NUM	127	1324 RE(Z3) ph-E	17,636		0.05-600 ohms	
BOTH	128	1325 T3 DELAY	0,8		0-30 sec	
TEXT	129	1331 Op. mode Z4	Reverse		Fwd/Rev/Non/Inacti	
NUM	130	1332 R(Z4) ph-ph	0,571		0.05-600 ohms	
NUM	131	1333 X(Z4)	0,617		0.05-600 ohms	
NUM	132	1334 RE(Z4) ph-E	1,321		0.05-600 ohms	
NUM	69	1116 RE/RL(Z1)	1,19		-0.33-7	
NUM	70	1117 XE/XL(Z1)	1,48		-0.33-7	
NUM	71	1118 RE/RL(Z1B...Z5)	1,19		-0.33-7	
NUM	72	1119 XE/XL(Z1B...Z5)	1,48		-0.33-7	



Location | Device Remarks

Local Zone of Protection Data

Substation: Chumdo

LZOP ID: LINE 10

Name: 66kV Chukha feeder

LZOP Rank: 1

Change LZOP | View LZOP

Device Tag: 68

Relay Tag: 66

Archived

Device Name: REL511_CHP Fdr.

Active Group

<< Advanced

Group Displayed | Rename | Copy | Delete | Compare | Move

Relay Style: REL511_V2.3_1A | Select Style

Scheme: MAIN

Manufacturer: ABB

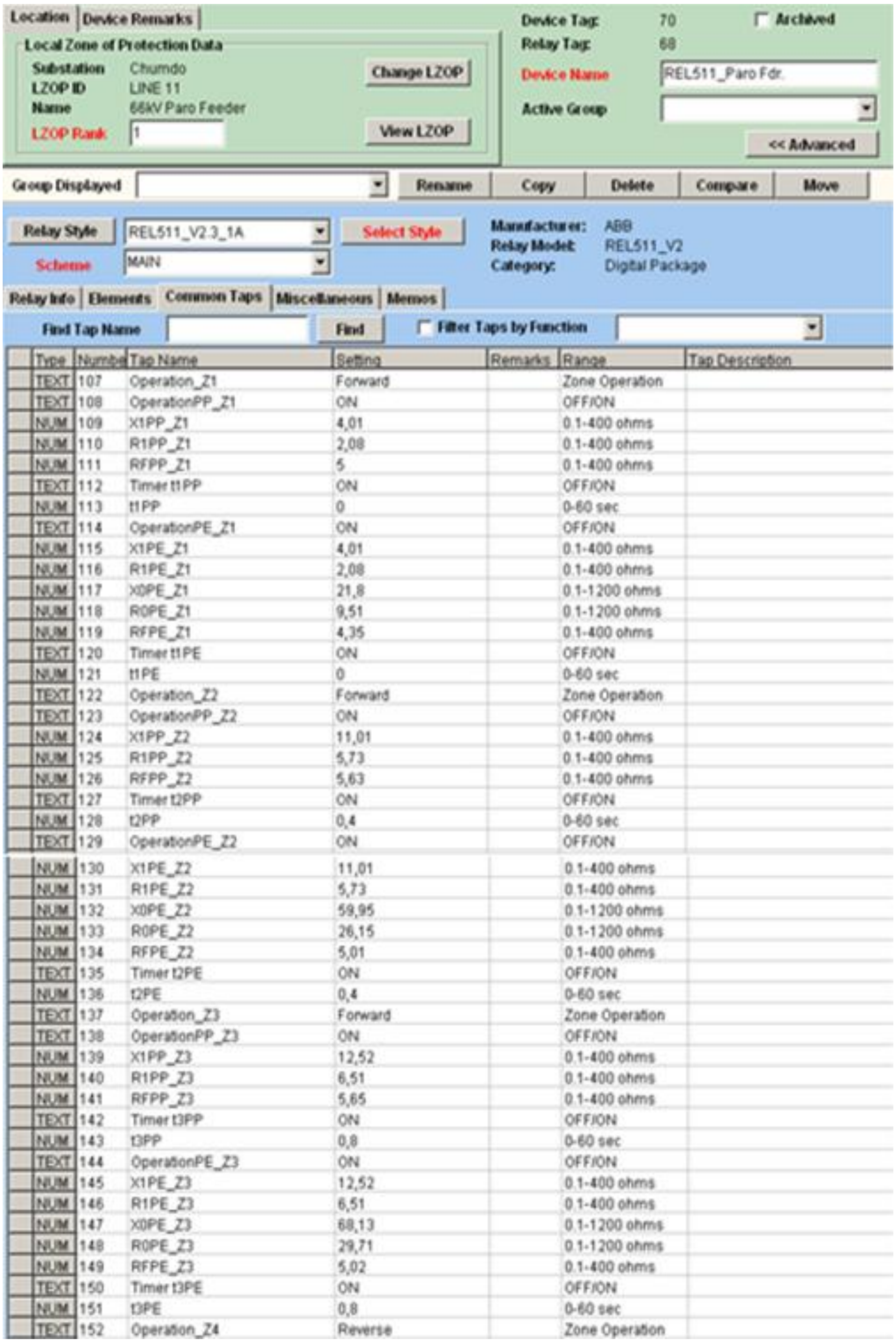
Relay Model: REL511_V2

Category: Digital Package

Relay Info | Elements | Common Taps | Miscellaneous | Memos

Find Tap Name | Find | Filter Taps by Function

Type	Number	Tap Name	Setting	Remarks	Range	Tap Description
TEXT	107	Operation_Z1	Forward		Zone Operation	
TEXT	108	OperationPP_Z1	ON		OFF/ON	
NUM	109	X1PP_Z1	6,17		0.1-400 ohms	
NUM	110	R1PP_Z1	3,21		0.1-400 ohms	
NUM	111	RFPP_Z1	22,23		0.1-400 ohms	
TEXT	112	Timer t1PP	ON		OFF/ON	
NUM	113	t1PP	0		0-60 sec	
TEXT	114	OperationPE_Z1	ON		OFF/ON	
NUM	115	X1PE_Z1	6,17		0.1-400 ohms	
NUM	116	R1PE_Z1	3,21		0.1-400 ohms	
NUM	117	X0PE_Z1	33,58		0.1-1200 ohms	
NUM	118	R0PE_Z1	14,64		0.1-1200 ohms	
NUM	119	RFPE_Z1	18,75		0.1-400 ohms	
TEXT	120	Timer t1PE	ON		OFF/ON	
NUM	121	t1PE	0		0-60 sec	
TEXT	122	Operation_Z2	Forward		Zone Operation	
TEXT	123	OperationPP_Z2	ON		OFF/ON	
NUM	124	X1PP_Z2	9,9		0.1-400 ohms	
NUM	125	R1PP_Z2	5,15		0.1-400 ohms	
NUM	126	RFPP_Z2	26,79		0.1-400 ohms	
TEXT	127	Timer t2PP	ON		OFF/ON	
NUM	128	t2PP	0,4		0-60 sec	
TEXT	129	OperationPE_Z2	ON		OFF/ON	
NUM	130	X1PE_Z2	9,9		0.1-400 ohms	
NUM	131	R1PE_Z2	5,15		0.1-400 ohms	
NUM	132	X0PE_Z2	53,89		0.1-1200 ohms	
NUM	133	R0PE_Z2	23,5		0.1-1200 ohms	
NUM	134	RFPE_Z2	20,15		0.1-400 ohms	
TEXT	135	Timer t2PE	ON		OFF/ON	
NUM	136	t2PE	0,4		0-60 sec	
TEXT	137	Operation_Z3	Forward		Zone Operation	
TEXT	138	OperationPP_Z3	ON		OFF/ON	
NUM	139	X1PP_Z3	12,09		0.1-400 ohms	
NUM	140	R1PP_Z3	6,29		0.1-400 ohms	
NUM	141	RFPP_Z3	26,84		0.1-400 ohms	
TEXT	142	Timer t3PP	ON		OFF/ON	
NUM	143	t3PP	0,8		0-60 sec	
TEXT	144	OperationPE_Z3	ON		OFF/ON	
NUM	145	X1PE_Z3	12,09		0.1-400 ohms	
NUM	146	R1PE_Z3	6,29		0.1-400 ohms	
NUM	147	X0PE_Z3	65,81		0.1-1200 ohms	
NUM	148	R0PE_Z3	28,7		0.1-1200 ohms	
NUM	149	RFPE_Z3	23,44		0.1-400 ohms	
TEXT	150	Timer t3PE	ON		OFF/ON	
NUM	151	t3PE	0,8		0-60 sec	
TEXT	152	Operation_Z4	Reverse		Zone Operation	



Location | Device Remarks

Local Zone of Protection Data

Substation: Chumdo
LZOP ID: LINE 11
Name: 66kV Paro Feeder
LZOP Rank: 1

Change LZOP | View LZOP

Device Tag: 70 | Archived
Relay Tag: 68
Device Name: REL511_Paro Fdr.
Active Group:
<< Advanced

Group Displayed: | Rename | Copy | Delete | Compare | Move

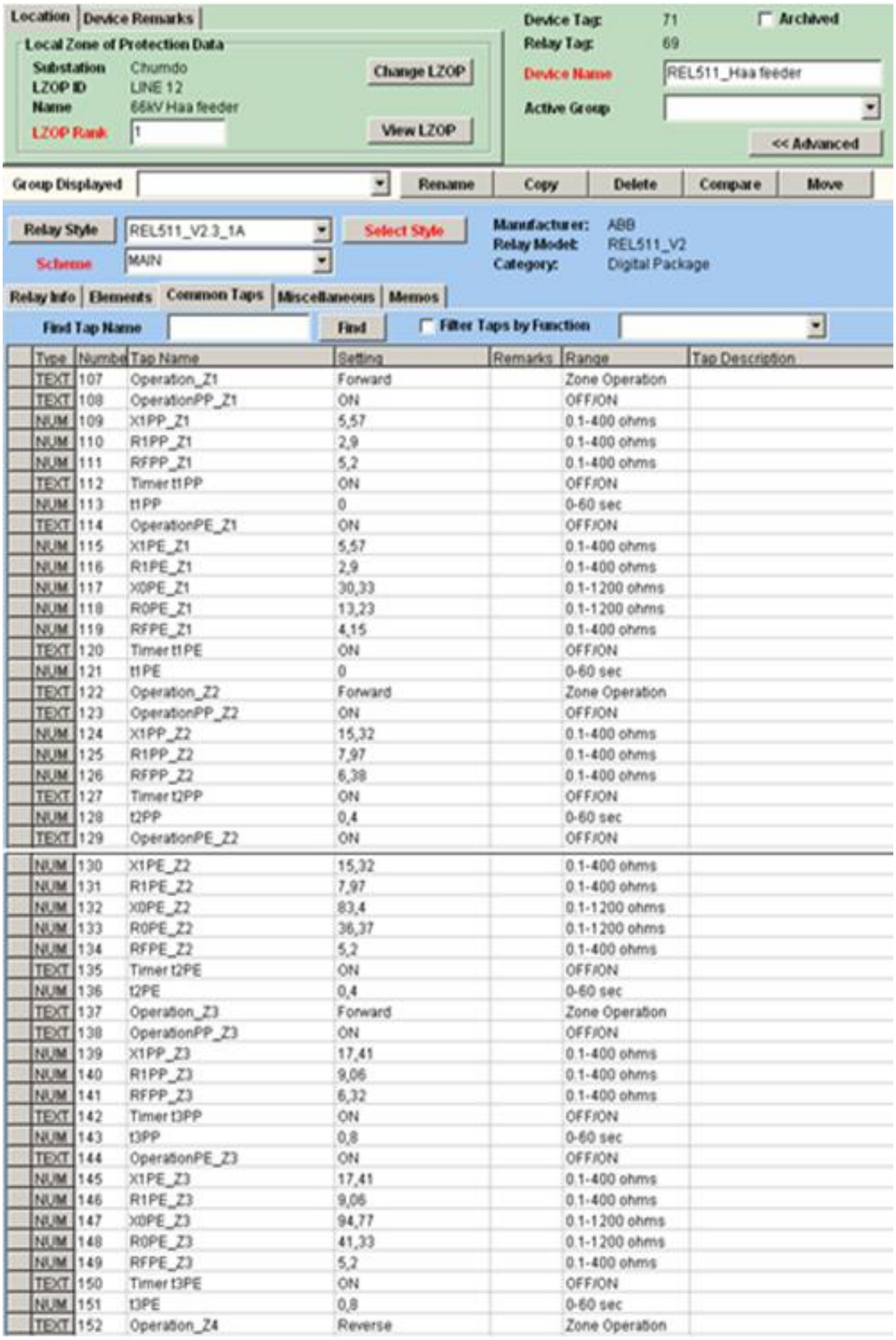
Relay Style: REL511_V2.3_1A | Select Style
Scheme: MAIN

Manufacturer: ABB
Relay Model: REL511_V2
Category: Digital Package

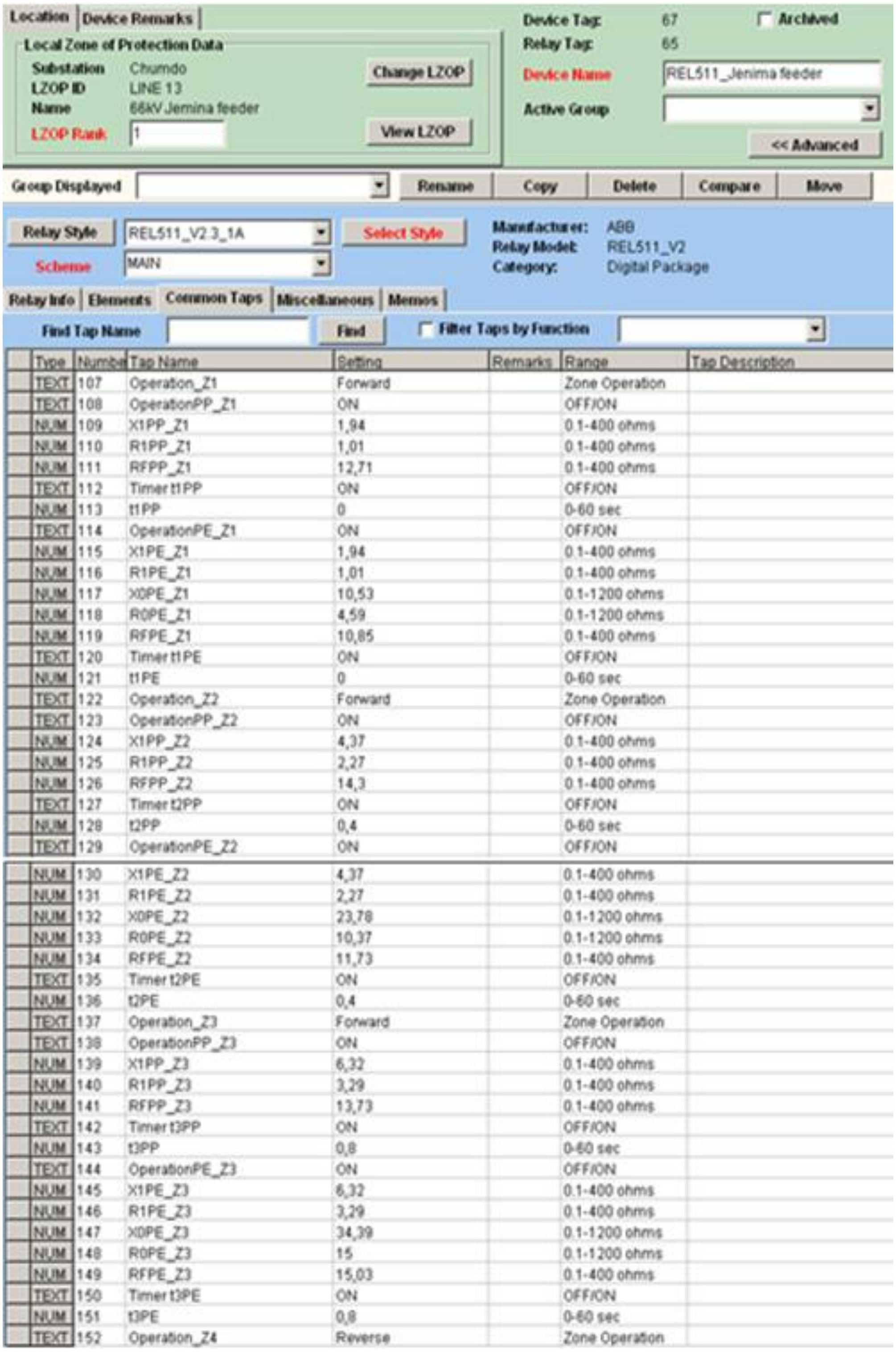
Relay Info | Elements | Common Taps | Miscellaneous | Memos

Find Tap Name: | Find | Filter Taps by Function

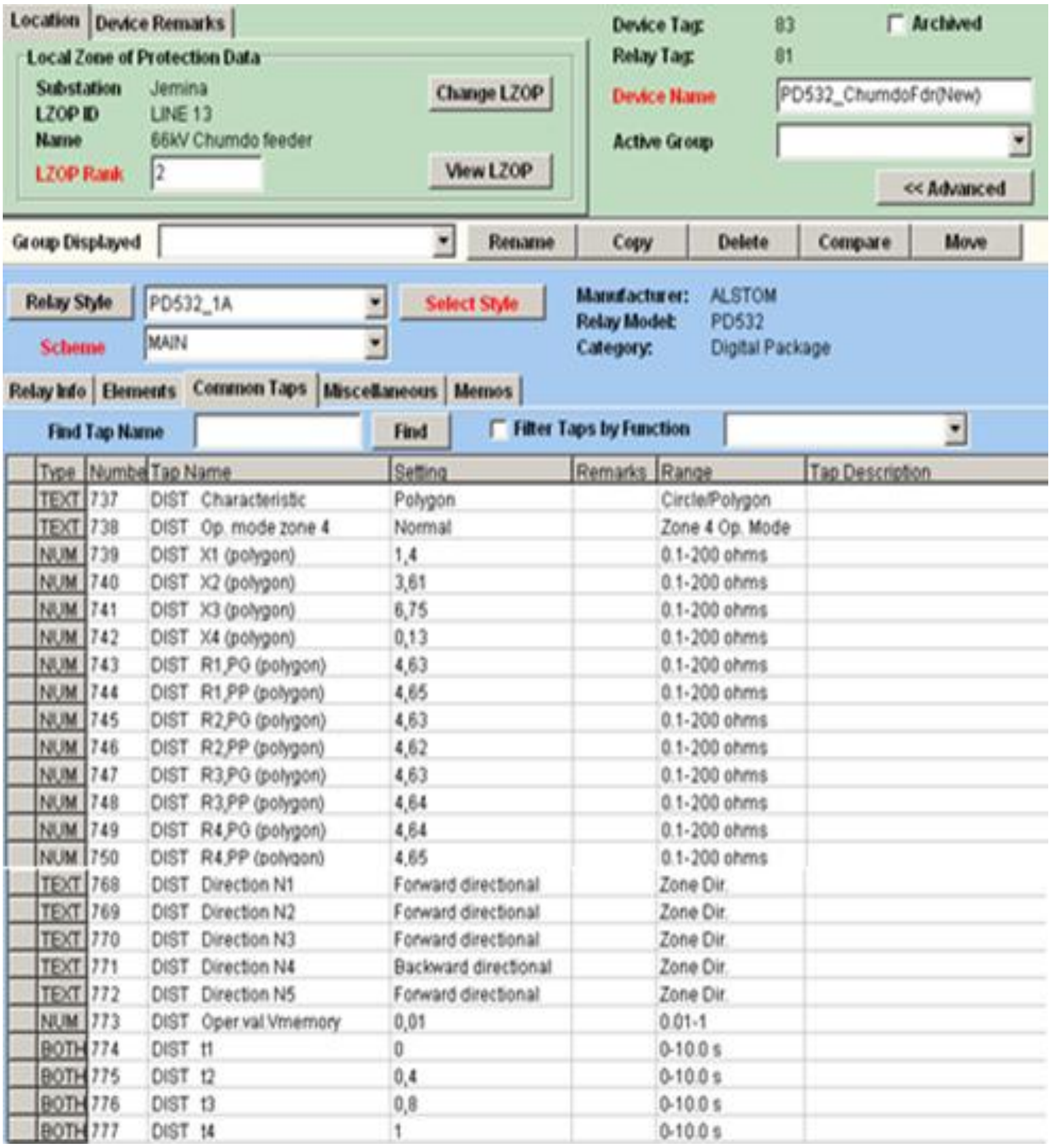
Type	Number	Tap Name	Setting	Remarks	Range	Tap Description
TEXT	107	Operation_Z1	Forward		Zone Operation	
TEXT	108	OperationPP_Z1	ON		OFF/ON	
NUM	109	X1PP_Z1	4,01		0.1-400 ohms	
NUM	110	R1PP_Z1	2,08		0.1-400 ohms	
NUM	111	RFPP_Z1	5		0.1-400 ohms	
TEXT	112	Timer t1PP	ON		OFF/ON	
NUM	113	t1PP	0		0-60 sec	
TEXT	114	OperationPE_Z1	ON		OFF/ON	
NUM	115	X1PE_Z1	4,01		0.1-400 ohms	
NUM	116	R1PE_Z1	2,08		0.1-400 ohms	
NUM	117	X0PE_Z1	21,8		0.1-1200 ohms	
NUM	118	R0PE_Z1	9,51		0.1-1200 ohms	
NUM	119	RFPE_Z1	4,35		0.1-400 ohms	
TEXT	120	Timer t1PE	ON		OFF/ON	
NUM	121	t1PE	0		0-60 sec	
TEXT	122	Operation_Z2	Forward		Zone Operation	
TEXT	123	OperationPP_Z2	ON		OFF/ON	
NUM	124	X1PP_Z2	11,01		0.1-400 ohms	
NUM	125	R1PP_Z2	5,73		0.1-400 ohms	
NUM	126	RFPP_Z2	5,63		0.1-400 ohms	
TEXT	127	Timer t2PP	ON		OFF/ON	
NUM	128	t2PP	0,4		0-60 sec	
TEXT	129	OperationPE_Z2	ON		OFF/ON	
NUM	130	X1PE_Z2	11,01		0.1-400 ohms	
NUM	131	R1PE_Z2	5,73		0.1-400 ohms	
NUM	132	X0PE_Z2	59,95		0.1-1200 ohms	
NUM	133	R0PE_Z2	26,15		0.1-1200 ohms	
NUM	134	RFPE_Z2	5,01		0.1-400 ohms	
TEXT	135	Timer t2PE	ON		OFF/ON	
NUM	136	t2PE	0,4		0-60 sec	
TEXT	137	Operation_Z3	Forward		Zone Operation	
TEXT	138	OperationPP_Z3	ON		OFF/ON	
NUM	139	X1PP_Z3	12,52		0.1-400 ohms	
NUM	140	R1PP_Z3	6,51		0.1-400 ohms	
NUM	141	RFPP_Z3	5,65		0.1-400 ohms	
TEXT	142	Timer t3PP	ON		OFF/ON	
NUM	143	t3PP	0,8		0-60 sec	
TEXT	144	OperationPE_Z3	ON		OFF/ON	
NUM	145	X1PE_Z3	12,52		0.1-400 ohms	
NUM	146	R1PE_Z3	6,51		0.1-400 ohms	
NUM	147	X0PE_Z3	68,13		0.1-1200 ohms	
NUM	148	R0PE_Z3	29,71		0.1-1200 ohms	
NUM	149	RFPE_Z3	5,02		0.1-400 ohms	
TEXT	150	Timer t3PE	ON		OFF/ON	
NUM	151	t3PE	0,8		0-60 sec	
TEXT	152	Operation_Z4	Reverse		Zone Operation	



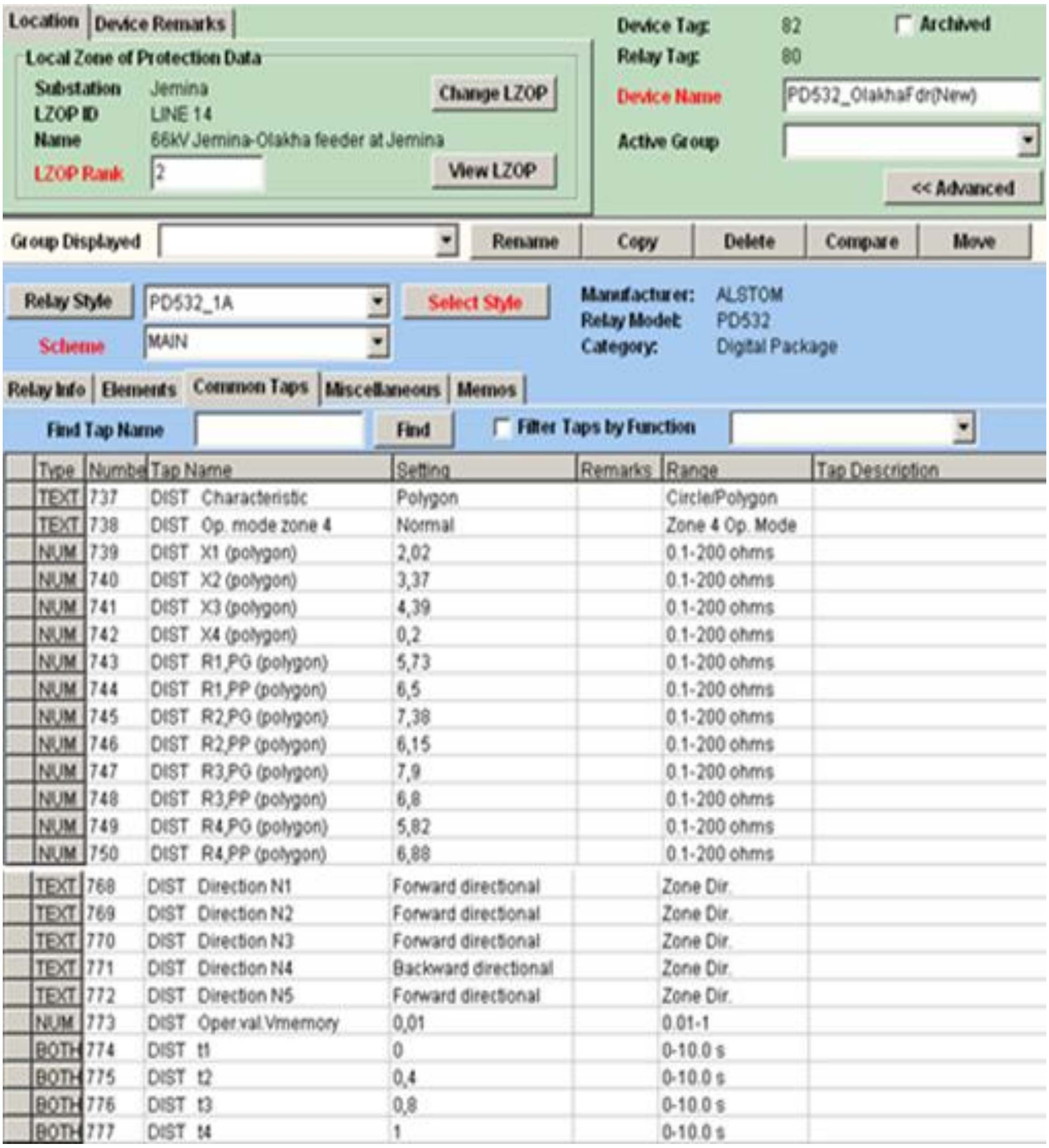
Type	Number	Tap Name	Setting	Remarks	Range	Tap Description
TEXT	107	Operation_Z1	Forward		Zone Operation	
TEXT	108	OperationPP_Z1	ON		OFF/ON	
NUM	109	X1PP_Z1	5,57		0.1-400 ohms	
NUM	110	R1PP_Z1	2,9		0.1-400 ohms	
NUM	111	RFPP_Z1	5,2		0.1-400 ohms	
TEXT	112	Timer t1PP	ON		OFF/ON	
NUM	113	t1PP	0		0-60 sec	
TEXT	114	OperationPE_Z1	ON		OFF/ON	
NUM	115	X1PE_Z1	5,57		0.1-400 ohms	
NUM	116	R1PE_Z1	2,9		0.1-400 ohms	
NUM	117	X0PE_Z1	30,33		0.1-1200 ohms	
NUM	118	R0PE_Z1	13,23		0.1-1200 ohms	
NUM	119	RFPE_Z1	4,15		0.1-400 ohms	
TEXT	120	Timer t1PE	ON		OFF/ON	
NUM	121	t1PE	0		0-60 sec	
TEXT	122	Operation_Z2	Forward		Zone Operation	
TEXT	123	OperationPP_Z2	ON		OFF/ON	
NUM	124	X1PP_Z2	15,32		0.1-400 ohms	
NUM	125	R1PP_Z2	7,97		0.1-400 ohms	
NUM	126	RFPP_Z2	6,38		0.1-400 ohms	
TEXT	127	Timer t2PP	ON		OFF/ON	
NUM	128	t2PP	0,4		0-60 sec	
TEXT	129	OperationPE_Z2	ON		OFF/ON	
NUM	130	X1PE_Z2	15,32		0.1-400 ohms	
NUM	131	R1PE_Z2	7,97		0.1-400 ohms	
NUM	132	X0PE_Z2	83,4		0.1-1200 ohms	
NUM	133	R0PE_Z2	36,37		0.1-1200 ohms	
NUM	134	RFPE_Z2	5,2		0.1-400 ohms	
TEXT	135	Timer t2PE	ON		OFF/ON	
NUM	136	t2PE	0,4		0-60 sec	
TEXT	137	Operation_Z3	Forward		Zone Operation	
TEXT	138	OperationPP_Z3	ON		OFF/ON	
NUM	139	X1PP_Z3	17,41		0.1-400 ohms	
NUM	140	R1PP_Z3	9,06		0.1-400 ohms	
NUM	141	RFPP_Z3	6,32		0.1-400 ohms	
TEXT	142	Timer t3PP	ON		OFF/ON	
NUM	143	t3PP	0,8		0-60 sec	
TEXT	144	OperationPE_Z3	ON		OFF/ON	
NUM	145	X1PE_Z3	17,41		0.1-400 ohms	
NUM	146	R1PE_Z3	9,06		0.1-400 ohms	
NUM	147	X0PE_Z3	94,77		0.1-1200 ohms	
NUM	148	R0PE_Z3	41,33		0.1-1200 ohms	
NUM	149	RFPE_Z3	5,2		0.1-400 ohms	
TEXT	150	Timer t3PE	ON		OFF/ON	
NUM	151	t3PE	0,8		0-60 sec	
TEXT	152	Operation_Z4	Reverse		Zone Operation	



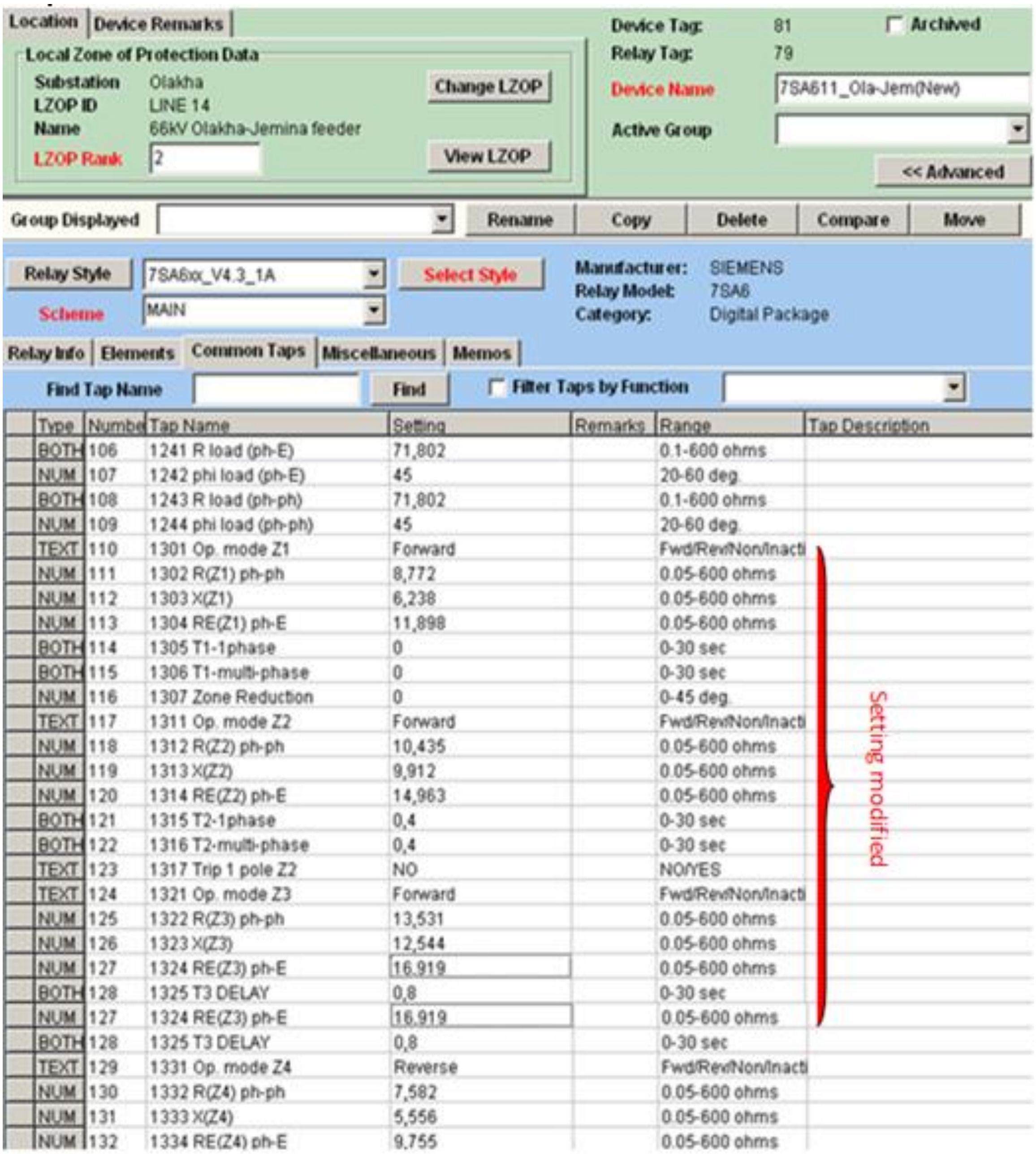
Type	Number	Tap Name	Setting	Remarks	Range	Tap Description
TEXT	107	Operation_Z1	Forward		Zone Operation	
TEXT	108	OperationPP_Z1	ON		OFF/ON	
NUM	109	X1PP_Z1	1,94		0.1-400 ohms	
NUM	110	R1PP_Z1	1,01		0.1-400 ohms	
NUM	111	RFPP_Z1	12,71		0.1-400 ohms	
TEXT	112	Timer t1PP	ON		OFF/ON	
NUM	113	t1PP	0		0-60 sec	
TEXT	114	OperationPE_Z1	ON		OFF/ON	
NUM	115	X1PE_Z1	1,94		0.1-400 ohms	
NUM	116	R1PE_Z1	1,01		0.1-400 ohms	
NUM	117	X0PE_Z1	10,53		0.1-1200 ohms	
NUM	118	R0PE_Z1	4,59		0.1-1200 ohms	
NUM	119	RFPE_Z1	10,85		0.1-400 ohms	
TEXT	120	Timer t1PE	ON		OFF/ON	
NUM	121	t1PE	0		0-60 sec	
TEXT	122	Operation_Z2	Forward		Zone Operation	
TEXT	123	OperationPP_Z2	ON		OFF/ON	
NUM	124	X1PP_Z2	4,37		0.1-400 ohms	
NUM	125	R1PP_Z2	2,27		0.1-400 ohms	
NUM	126	RFPP_Z2	14,3		0.1-400 ohms	
TEXT	127	Timer t2PP	ON		OFF/ON	
NUM	128	t2PP	0,4		0-60 sec	
TEXT	129	OperationPE_Z2	ON		OFF/ON	
NUM	130	X1PE_Z2	4,37		0.1-400 ohms	
NUM	131	R1PE_Z2	2,27		0.1-400 ohms	
NUM	132	X0PE_Z2	23,78		0.1-1200 ohms	
NUM	133	R0PE_Z2	10,37		0.1-1200 ohms	
NUM	134	RFPE_Z2	11,73		0.1-400 ohms	
TEXT	135	Timer t2PE	ON		OFF/ON	
NUM	136	t2PE	0,4		0-60 sec	
TEXT	137	Operation_Z3	Forward		Zone Operation	
TEXT	138	OperationPP_Z3	ON		OFF/ON	
NUM	139	X1PP_Z3	6,32		0.1-400 ohms	
NUM	140	R1PP_Z3	3,29		0.1-400 ohms	
NUM	141	RFPP_Z3	13,73		0.1-400 ohms	
TEXT	142	Timer t3PP	ON		OFF/ON	
NUM	143	t3PP	0,8		0-60 sec	
TEXT	144	OperationPE_Z3	ON		OFF/ON	
NUM	145	X1PE_Z3	6,32		0.1-400 ohms	
NUM	146	R1PE_Z3	3,29		0.1-400 ohms	
NUM	147	X0PE_Z3	34,39		0.1-1200 ohms	
NUM	148	R0PE_Z3	15		0.1-1200 ohms	
NUM	149	RFPE_Z3	15,03		0.1-400 ohms	
TEXT	150	Timer t3PE	ON		OFF/ON	
NUM	151	t3PE	0,8		0-60 sec	
TEXT	152	Operation_Z4	Reverse		Zone Operation	



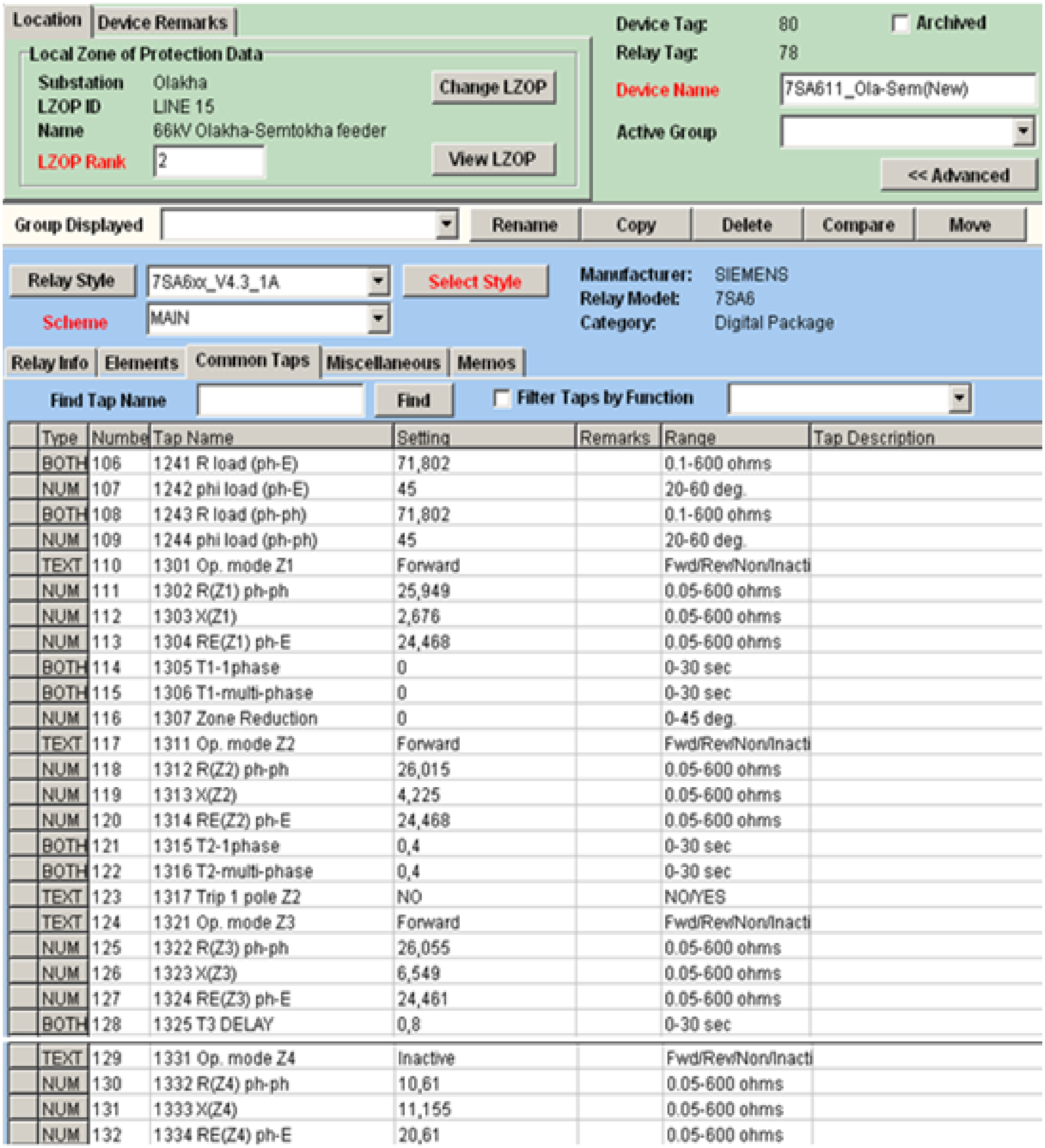
Type	Numbe	Tap Name	Setting	Remarks	Range	Tap Description
TEXT	737	DIST Characteristic	Polygon		Circle/Polygon	
TEXT	738	DIST Op. mode zone 4	Normal		Zone 4 Op. Mode	
NUM	739	DIST X1 (polygon)	1,4		0.1-200 ohms	
NUM	740	DIST X2 (polygon)	3,61		0.1-200 ohms	
NUM	741	DIST X3 (polygon)	6,75		0.1-200 ohms	
NUM	742	DIST X4 (polygon)	0,13		0.1-200 ohms	
NUM	743	DIST R1,PG (polygon)	4,63		0.1-200 ohms	
NUM	744	DIST R1,PP (polygon)	4,65		0.1-200 ohms	
NUM	745	DIST R2,PG (polygon)	4,63		0.1-200 ohms	
NUM	746	DIST R2,PP (polygon)	4,62		0.1-200 ohms	
NUM	747	DIST R3,PG (polygon)	4,63		0.1-200 ohms	
NUM	748	DIST R3,PP (polygon)	4,64		0.1-200 ohms	
NUM	749	DIST R4,PG (polygon)	4,64		0.1-200 ohms	
NUM	750	DIST R4,PP (polygon)	4,65		0.1-200 ohms	
TEXT	768	DIST Direction N1	Forward directional		Zone Dir.	
TEXT	769	DIST Direction N2	Forward directional		Zone Dir.	
TEXT	770	DIST Direction N3	Forward directional		Zone Dir.	
TEXT	771	DIST Direction N4	Backward directional		Zone Dir.	
TEXT	772	DIST Direction N5	Forward directional		Zone Dir.	
NUM	773	DIST Oper.val.Vmemory	0,01		0.01-1	
BOTH	774	DIST t1	0		0-10.0 s	
BOTH	775	DIST t2	0,4		0-10.0 s	
BOTH	776	DIST t3	0,8		0-10.0 s	
BOTH	777	DIST t4	1		0-10.0 s	



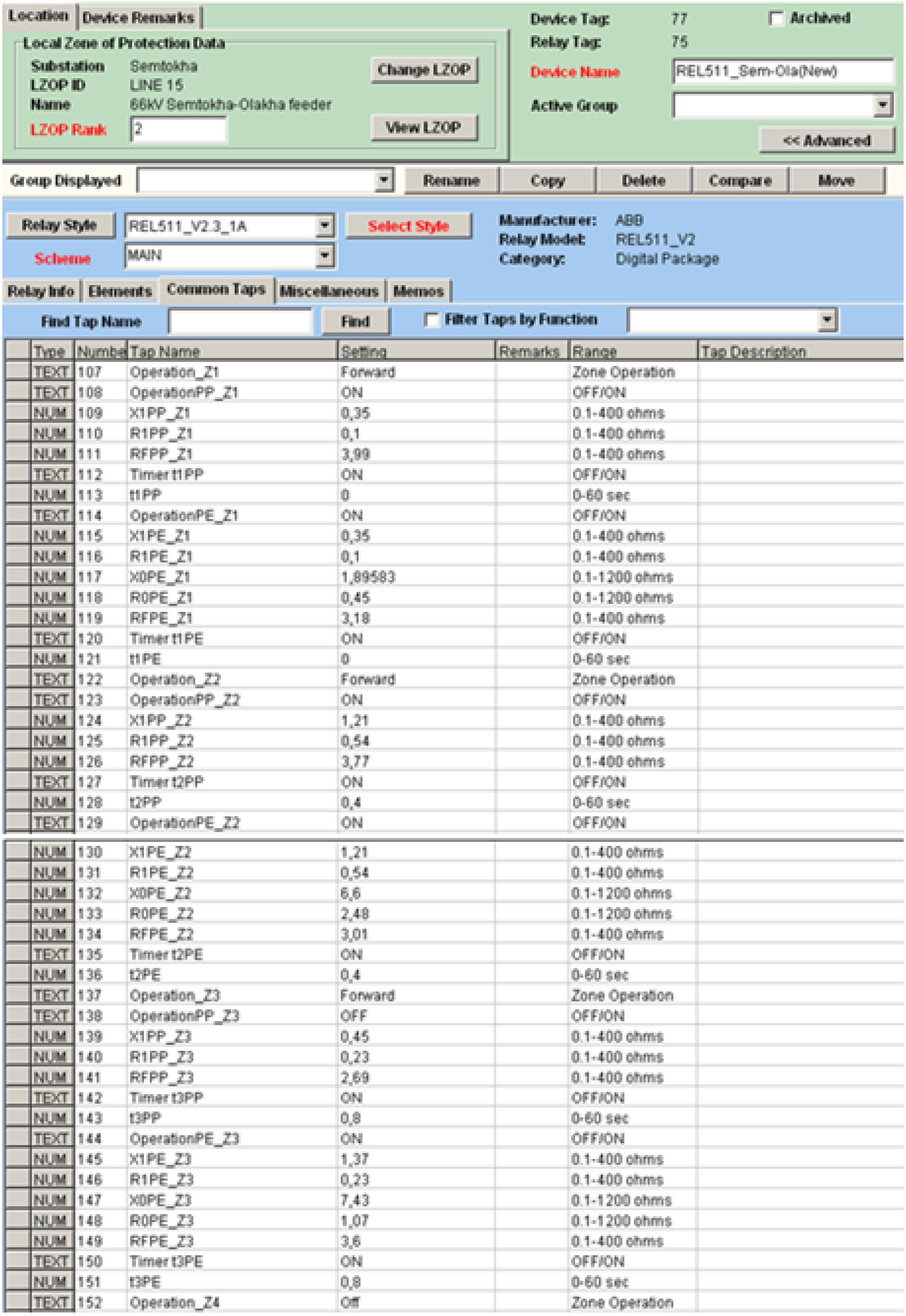
Type	Number	Tap Name	Setting	Remarks	Range	Tap Description
TEXT	737	DIST Characteristic	Polygon		Circle/Polygon	
TEXT	738	DIST Op. mode zone 4	Normal		Zone 4 Op. Mode	
NUM	739	DIST X1 (polygon)	2,02		0.1-200 ohms	
NUM	740	DIST X2 (polygon)	3,37		0.1-200 ohms	
NUM	741	DIST X3 (polygon)	4,39		0.1-200 ohms	
NUM	742	DIST X4 (polygon)	0,2		0.1-200 ohms	
NUM	743	DIST R1,PG (polygon)	5,73		0.1-200 ohms	
NUM	744	DIST R1,PP (polygon)	6,5		0.1-200 ohms	
NUM	745	DIST R2,PG (polygon)	7,38		0.1-200 ohms	
NUM	746	DIST R2,PP (polygon)	6,15		0.1-200 ohms	
NUM	747	DIST R3,PG (polygon)	7,9		0.1-200 ohms	
NUM	748	DIST R3,PP (polygon)	6,8		0.1-200 ohms	
NUM	749	DIST R4,PG (polygon)	5,82		0.1-200 ohms	
NUM	750	DIST R4,PP (polygon)	6,88		0.1-200 ohms	
TEXT	768	DIST Direction N1	Forward directional		Zone Dir.	
TEXT	769	DIST Direction N2	Forward directional		Zone Dir.	
TEXT	770	DIST Direction N3	Forward directional		Zone Dir.	
TEXT	771	DIST Direction N4	Backward directional		Zone Dir.	
TEXT	772	DIST Direction N5	Forward directional		Zone Dir.	
NUM	773	DIST Oper.val.Vmemory	0,01		0.01-1	
BOTH	774	DIST t1	0		0-10.0 s	
BOTH	775	DIST t2	0,4		0-10.0 s	
BOTH	776	DIST t3	0,8		0-10.0 s	
BOTH	777	DIST t4	1		0-10.0 s	



Type	Numbe	Tap Name	Setting	Remarks	Range	Tap Description
BOTH	106	1241 R load (ph-E)	71,802		0.1-600 ohms	
NUM	107	1242 phi load (ph-E)	45		20-60 deg.	
BOTH	108	1243 R load (ph-ph)	71,802		0.1-600 ohms	
NUM	109	1244 phi load (ph-ph)	45		20-60 deg.	
TEXT	110	1301 Op. mode Z1	Forward		Fwd/Rev/Non/Inacti	
NUM	111	1302 R(Z1) ph-ph	8,772		0.05-600 ohms	
NUM	112	1303 X(Z1)	6,238		0.05-600 ohms	
NUM	113	1304 RE(Z1) ph-E	11,898		0.05-600 ohms	
BOTH	114	1305 T1-1phase	0		0-30 sec	
BOTH	115	1306 T1-multi-phase	0		0-30 sec	
NUM	116	1307 Zone Reduction	0		0-45 deg.	
TEXT	117	1311 Op. mode Z2	Forward		Fwd/Rev/Non/Inacti	
NUM	118	1312 R(Z2) ph-ph	10,435		0.05-600 ohms	
NUM	119	1313 X(Z2)	9,912		0.05-600 ohms	
NUM	120	1314 RE(Z2) ph-E	14,963		0.05-600 ohms	
BOTH	121	1315 T2-1phase	0,4		0-30 sec	
BOTH	122	1316 T2-multi-phase	0,4		0-30 sec	
TEXT	123	1317 Trip 1 pole Z2	NO		NO/YES	
TEXT	124	1321 Op. mode Z3	Forward		Fwd/Rev/Non/Inacti	
NUM	125	1322 R(Z3) ph-ph	13,531		0.05-600 ohms	
NUM	126	1323 X(Z3)	12,544		0.05-600 ohms	
NUM	127	1324 RE(Z3) ph-E	16,919		0.05-600 ohms	
BOTH	128	1325 T3 DELAY	0,8		0-30 sec	
NUM	127	1324 RE(Z3) ph-E	16,919		0.05-600 ohms	
BOTH	128	1325 T3 DELAY	0,8		0-30 sec	
TEXT	129	1331 Op. mode Z4	Reverse		Fwd/Rev/Non/Inacti	
NUM	130	1332 R(Z4) ph-ph	7,582		0.05-600 ohms	
NUM	131	1333 X(Z4)	5,556		0.05-600 ohms	
NUM	132	1334 RE(Z4) ph-E	9,755		0.05-600 ohms	



Type	Numbe	Tap Name	Setting	Remarks	Range	Tap Description
BOTH	106	1241 R load (ph-E)	71,802		0.1-600 ohms	
NUM	107	1242 phi load (ph-E)	45		20-60 deg.	
BOTH	108	1243 R load (ph-ph)	71,802		0.1-600 ohms	
NUM	109	1244 phi load (ph-ph)	45		20-60 deg.	
TEXT	110	1301 Op. mode Z1	Forward		Fwd/Rev/Non/Inacti	
NUM	111	1302 R(Z1) ph-ph	25,949		0.05-600 ohms	
NUM	112	1303 X(Z1)	2,676		0.05-600 ohms	
NUM	113	1304 RE(Z1) ph-E	24,468		0.05-600 ohms	
BOTH	114	1305 T1-1phase	0		0-30 sec	
BOTH	115	1306 T1-multi-phase	0		0-30 sec	
NUM	116	1307 Zone Reduction	0		0-45 deg.	
TEXT	117	1311 Op. mode Z2	Forward		Fwd/Rev/Non/Inacti	
NUM	118	1312 R(Z2) ph-ph	26,015		0.05-600 ohms	
NUM	119	1313 X(Z2)	4,225		0.05-600 ohms	
NUM	120	1314 RE(Z2) ph-E	24,468		0.05-600 ohms	
BOTH	121	1315 T2-1phase	0,4		0-30 sec	
BOTH	122	1316 T2-multi-phase	0,4		0-30 sec	
TEXT	123	1317 Trip 1 pole Z2	NO		NO/YES	
TEXT	124	1321 Op. mode Z3	Forward		Fwd/Rev/Non/Inacti	
NUM	125	1322 R(Z3) ph-ph	26,055		0.05-600 ohms	
NUM	126	1323 X(Z3)	6,549		0.05-600 ohms	
NUM	127	1324 RE(Z3) ph-E	24,461		0.05-600 ohms	
BOTH	128	1325 T3 DELAY	0,8		0-30 sec	
TEXT	129	1331 Op. mode Z4	Inactive		Fwd/Rev/Non/Inacti	
NUM	130	1332 R(Z4) ph-ph	10,61		0.05-600 ohms	
NUM	131	1333 X(Z4)	11,155		0.05-600 ohms	
NUM	132	1334 RE(Z4) ph-E	20,61		0.05-600 ohms	



Location | Device Remarks

Local Zone of Protection Data

Substation: Semtokha
LZOP ID: LINE 15
Name: 66kV Semtokha-Olakha feeder
LZOP Rank: 2

Change LZOP | View LZOP

Device Tag: 77 | Archived
Relay Tag: 75
Device Name: REL511_Sem-Ola(New)
Active Group:
<< Advanced

Group Displayed: | Rename | Copy | Delete | Compare | Move

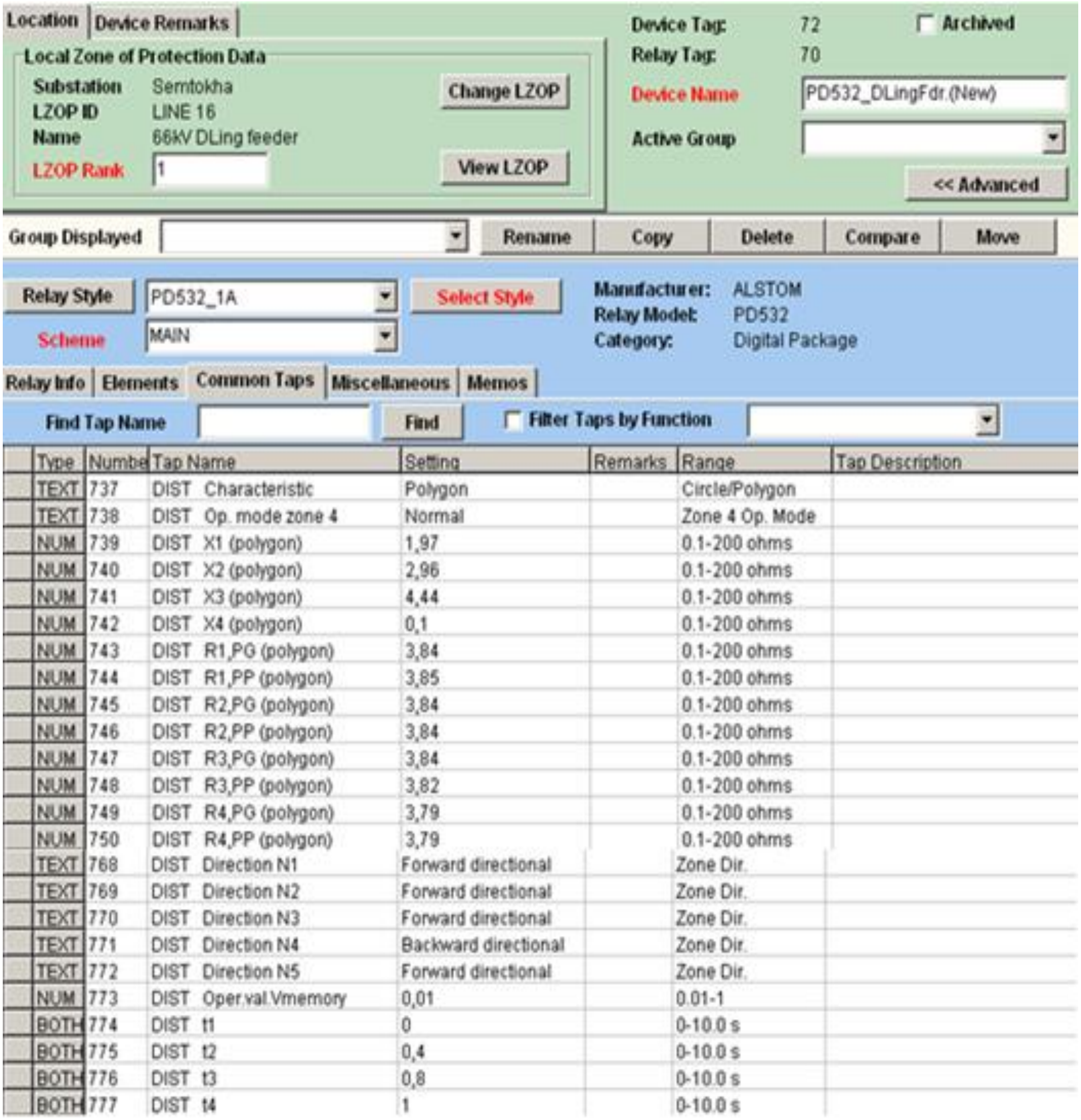
Relay Style: REL511_V2.3_1A | Select Style
Scheme: MAIN

Manufacturer: ABB
Relay Model: REL511_V2
Category: Digital Package

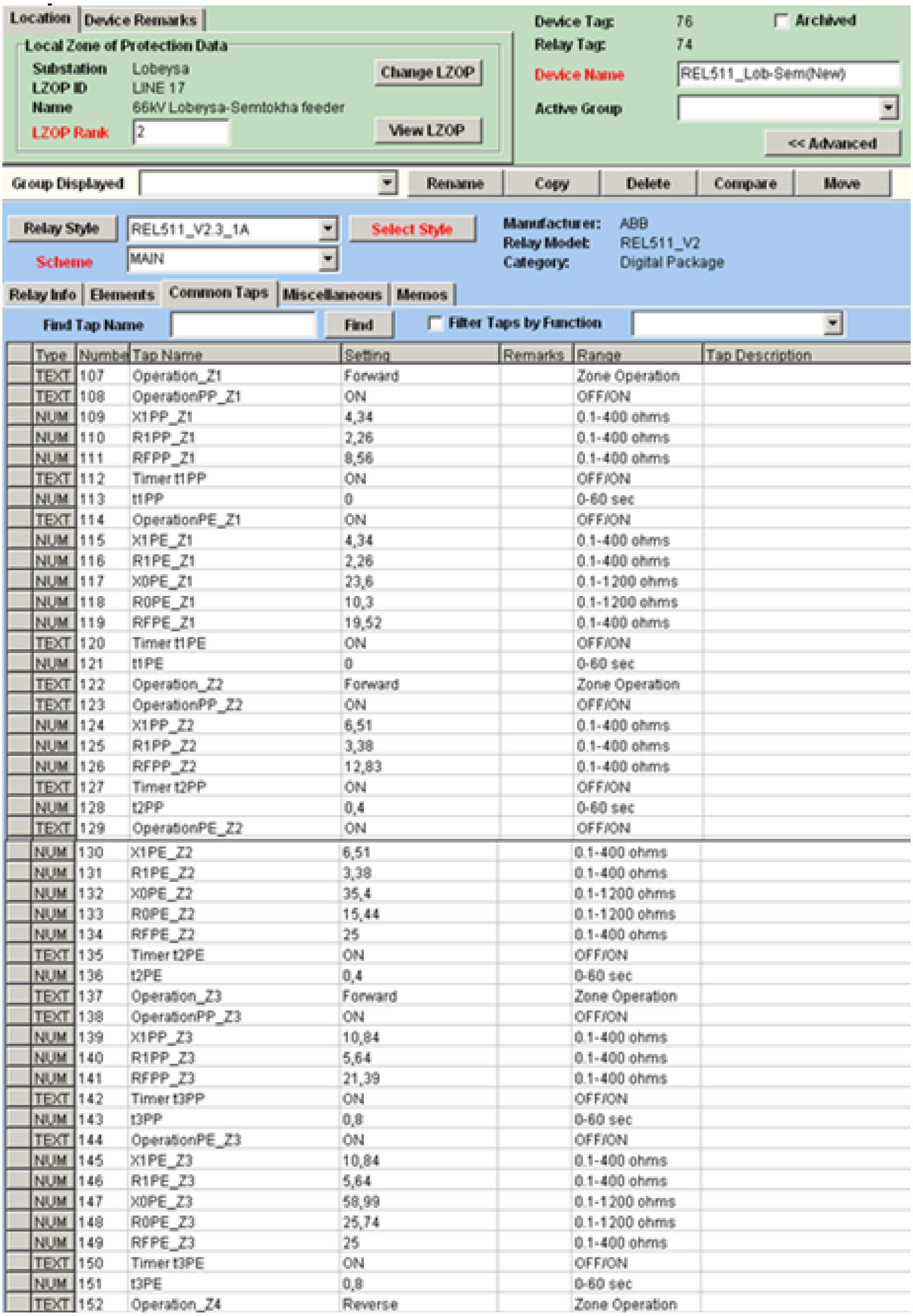
Relay Info | Elements | Common Taps | Miscellaneous | Memos

Find Tap Name | Find | Filter Taps by Function

Type	Numbe	Tap Name	Setting	Remarks	Range	Tap Description
TEXT	107	Operation_Z1	Forward		Zone Operation	
TEXT	108	OperationPP_Z1	ON		OFF/ON	
NUM	109	X1PP_Z1	0,35		0.1-400 ohms	
NUM	110	R1PP_Z1	0,1		0.1-400 ohms	
NUM	111	RFPP_Z1	3,99		0.1-400 ohms	
TEXT	112	Timer t1PP	ON		OFF/ON	
NUM	113	t1PP	0		0-60 sec	
TEXT	114	OperationPE_Z1	ON		OFF/ON	
NUM	115	X1PE_Z1	0,35		0.1-400 ohms	
NUM	116	R1PE_Z1	0,1		0.1-400 ohms	
NUM	117	X0PE_Z1	1,89583		0.1-1200 ohms	
NUM	118	R0PE_Z1	0,45		0.1-1200 ohms	
NUM	119	RFPE_Z1	3,18		0.1-400 ohms	
TEXT	120	Timer t1PE	ON		OFF/ON	
NUM	121	t1PE	0		0-60 sec	
TEXT	122	Operation_Z2	Forward		Zone Operation	
TEXT	123	OperationPP_Z2	ON		OFF/ON	
NUM	124	X1PP_Z2	1,21		0.1-400 ohms	
NUM	125	R1PP_Z2	0,54		0.1-400 ohms	
NUM	126	RFPP_Z2	3,77		0.1-400 ohms	
TEXT	127	Timer t2PP	ON		OFF/ON	
NUM	128	t2PP	0,4		0-60 sec	
TEXT	129	OperationPE_Z2	ON		OFF/ON	
NUM	130	X1PE_Z2	1,21		0.1-400 ohms	
NUM	131	R1PE_Z2	0,54		0.1-400 ohms	
NUM	132	X0PE_Z2	6,6		0.1-1200 ohms	
NUM	133	R0PE_Z2	2,48		0.1-1200 ohms	
NUM	134	RFPE_Z2	3,01		0.1-400 ohms	
TEXT	135	Timer t2PE	ON		OFF/ON	
NUM	136	t2PE	0,4		0-60 sec	
TEXT	137	Operation_Z3	Forward		Zone Operation	
TEXT	138	OperationPP_Z3	OFF		OFF/ON	
NUM	139	X1PP_Z3	0,45		0.1-400 ohms	
NUM	140	R1PP_Z3	0,23		0.1-400 ohms	
NUM	141	RFPP_Z3	2,69		0.1-400 ohms	
TEXT	142	Timer t3PP	ON		OFF/ON	
NUM	143	t3PP	0,8		0-60 sec	
TEXT	144	OperationPE_Z3	ON		OFF/ON	
NUM	145	X1PE_Z3	1,37		0.1-400 ohms	
NUM	146	R1PE_Z3	0,23		0.1-400 ohms	
NUM	147	X0PE_Z3	7,43		0.1-1200 ohms	
NUM	148	R0PE_Z3	1,07		0.1-1200 ohms	
NUM	149	RFPE_Z3	3,6		0.1-400 ohms	
TEXT	150	Timer t3PE	ON		OFF/ON	
NUM	151	t3PE	0,8		0-60 sec	
TEXT	152	Operation_Z4	Off		Zone Operation	



Type	Numbe	Tap Name	Setting	Remarks	Range	Tap Description
TEXT	737	DIST Characteristic	Polygon		Circle/Polygon	
TEXT	738	DIST Op. mode zone 4	Normal		Zone 4 Op. Mode	
NUM	739	DIST X1 (polygon)	1,97		0.1-200 ohms	
NUM	740	DIST X2 (polygon)	2,96		0.1-200 ohms	
NUM	741	DIST X3 (polygon)	4,44		0.1-200 ohms	
NUM	742	DIST X4 (polygon)	0,1		0.1-200 ohms	
NUM	743	DIST R1,PG (polygon)	3,84		0.1-200 ohms	
NUM	744	DIST R1,PP (polygon)	3,85		0.1-200 ohms	
NUM	745	DIST R2,PG (polygon)	3,84		0.1-200 ohms	
NUM	746	DIST R2,PP (polygon)	3,84		0.1-200 ohms	
NUM	747	DIST R3,PG (polygon)	3,84		0.1-200 ohms	
NUM	748	DIST R3,PP (polygon)	3,82		0.1-200 ohms	
NUM	749	DIST R4,PG (polygon)	3,79		0.1-200 ohms	
NUM	750	DIST R4,PP (polygon)	3,79		0.1-200 ohms	
TEXT	768	DIST Direction N1	Forward directional		Zone Dir.	
TEXT	769	DIST Direction N2	Forward directional		Zone Dir.	
TEXT	770	DIST Direction N3	Forward directional		Zone Dir.	
TEXT	771	DIST Direction N4	Backward directional		Zone Dir.	
TEXT	772	DIST Direction N5	Forward directional		Zone Dir.	
NUM	773	DIST Oper.val.Vmemory	0,01		0.01-1	
BOTH	774	DIST t1	0		0-10.0 s	
BOTH	775	DIST t2	0,4		0-10.0 s	
BOTH	776	DIST t3	0,8		0-10.0 s	
BOTH	777	DIST t4	1		0-10.0 s	



Type	Number	Tap Name	Setting	Remarks	Range	Tap Description
TEXT	107	Operation_Z1	Forward		Zone Operation	
TEXT	108	OperationPP_Z1	ON		OFF/ON	
NUM	109	X1PP_Z1	4,34		0.1-400 ohms	
NUM	110	R1PP_Z1	2,26		0.1-400 ohms	
NUM	111	RFPP_Z1	8,56		0.1-400 ohms	
TEXT	112	Timer t1PP	ON		OFF/ON	
NUM	113	t1PP	0		0-60 sec	
TEXT	114	OperationPE_Z1	ON		OFF/ON	
NUM	115	X1PE_Z1	4,34		0.1-400 ohms	
NUM	116	R1PE_Z1	2,26		0.1-400 ohms	
NUM	117	X0PE_Z1	23,6		0.1-1200 ohms	
NUM	118	R0PE_Z1	10,3		0.1-1200 ohms	
NUM	119	RFPE_Z1	19,52		0.1-400 ohms	
TEXT	120	Timer t1PE	ON		OFF/ON	
NUM	121	t1PE	0		0-60 sec	
TEXT	122	Operation_Z2	Forward		Zone Operation	
TEXT	123	OperationPP_Z2	ON		OFF/ON	
NUM	124	X1PP_Z2	6,51		0.1-400 ohms	
NUM	125	R1PP_Z2	3,38		0.1-400 ohms	
NUM	126	RFPP_Z2	12,83		0.1-400 ohms	
TEXT	127	Timer t2PP	ON		OFF/ON	
NUM	128	t2PP	0,4		0-60 sec	
TEXT	129	OperationPE_Z2	ON		OFF/ON	
NUM	130	X1PE_Z2	6,51		0.1-400 ohms	
NUM	131	R1PE_Z2	3,38		0.1-400 ohms	
NUM	132	X0PE_Z2	35,4		0.1-1200 ohms	
NUM	133	R0PE_Z2	15,44		0.1-1200 ohms	
NUM	134	RFPE_Z2	25		0.1-400 ohms	
TEXT	135	Timer t2PE	ON		OFF/ON	
NUM	136	t2PE	0,4		0-60 sec	
TEXT	137	Operation_Z3	Forward		Zone Operation	
TEXT	138	OperationPP_Z3	ON		OFF/ON	
NUM	139	X1PP_Z3	10,84		0.1-400 ohms	
NUM	140	R1PP_Z3	5,64		0.1-400 ohms	
NUM	141	RFPP_Z3	21,39		0.1-400 ohms	
TEXT	142	Timer t3PP	ON		OFF/ON	
NUM	143	t3PP	0,8		0-60 sec	
TEXT	144	OperationPE_Z3	ON		OFF/ON	
NUM	145	X1PE_Z3	10,84		0.1-400 ohms	
NUM	146	R1PE_Z3	5,64		0.1-400 ohms	
NUM	147	X0PE_Z3	58,99		0.1-1200 ohms	
NUM	148	R0PE_Z3	25,74		0.1-1200 ohms	
NUM	149	RFPE_Z3	25		0.1-400 ohms	
TEXT	150	Timer t3PE	ON		OFF/ON	
NUM	151	t3PE	0,8		0-60 sec	
TEXT	152	Operation_Z4	Reverse		Zone Operation	

Location | Device Remarks

Local Zone of Protection Data

Substation: Lobeysa
LZOP ID: LINE 19
Name: 66kV Lobeysa-Basochu feeder
LZOP Rank: 2

Change LZOP | View LZOP

Device Tag: 75 | Archived
Relay Tag: 73
Device Name: REL511_Lob-Ruri(New)
Active Group:

<< Advanced

Group Displayed: | Rename | Copy | Delete | Compare | Move

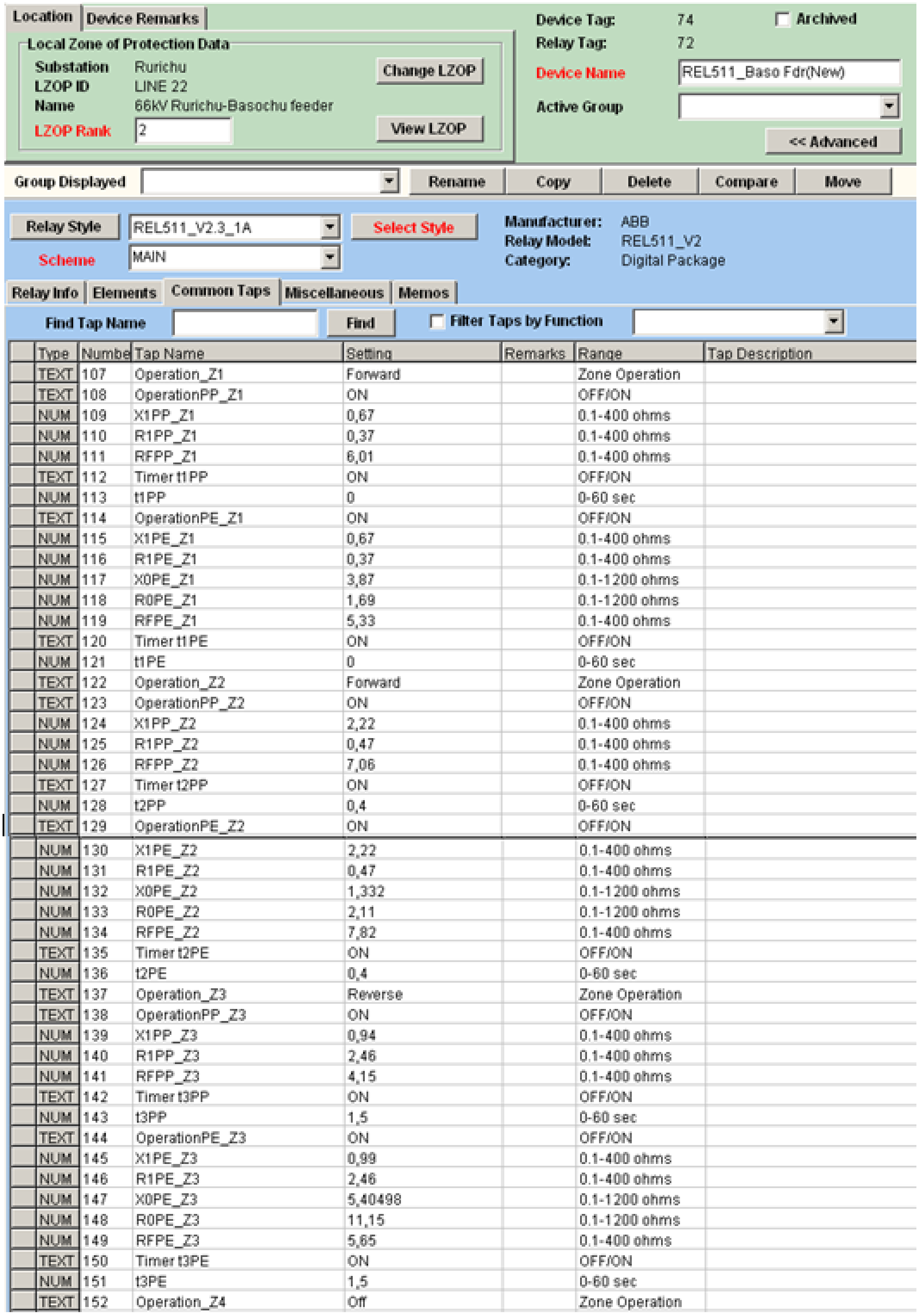
Relay Style: REL511_V2.3_1A | Select Style
Scheme: MAIN

Manufacturer: ABB
Relay Model: REL511_V2
Category: Digital Package

Relay Info | Elements | Common Taps | Miscellaneous | Memos

Find Tap Name | Find | Filter Taps by Function

Type	Number	Tap Name	Setting	Remarks	Range	Tap Description
TEXT	107	Operation_Z1	Forward		Zone Operation	
TEXT	108	OperationPP_Z1	ON		OFF/ON	
NUM	109	X1PP_Z1	3,52		0.1-400 ohms	
NUM	110	R1PP_Z1	1,83		0.1-400 ohms	
NUM	111	RFPP_Z1	11,5		0.1-400 ohms	
TEXT	112	Timer t1PP	ON		OFF/ON	
NUM	113	t1PP	0		0-60 sec	
TEXT	114	OperationPE_Z1	ON		OFF/ON	
NUM	115	X1PE_Z1	3,52		0.1-400 ohms	
NUM	116	R1PE_Z1	1,83		0.1-400 ohms	
NUM	117	X0PE_Z1	19,18		0.1-1200 ohms	
NUM	118	R0PE_Z1	8,36		0.1-1200 ohms	
NUM	119	RFPE_Z1	12,5		0.1-400 ohms	
TEXT	120	Timer t1PE	ON		OFF/ON	
NUM	121	t1PE	0		0-60 sec	
TEXT	122	Operation_Z2	Forward		Zone Operation	
TEXT	123	OperationPP_Z2	ON		OFF/ON	
NUM	124	X1PP_Z2	7,47		0.1-400 ohms	
NUM	125	R1PP_Z2	5,04		0.1-400 ohms	
NUM	126	RFPP_Z2	14		0.1-400 ohms	
TEXT	127	Timer t2PP	ON		OFF/ON	
NUM	128	t2PP	0,4		0-60 sec	
TEXT	129	OperationPE_Z2	ON		OFF/ON	
NUM	130	X1PE_Z2	7,46		0.1-400 ohms	
NUM	131	R1PE_Z2	5,04		0.1-400 ohms	
NUM	132	X0PE_Z2	40,6		0.1-1200 ohms	
NUM	133	R0PE_Z2	23		0.1-1200 ohms	
NUM	134	RFPE_Z2	15		0.1-400 ohms	
TEXT	135	Timer t2PE	ON		OFF/ON	
NUM	136	t2PE	0,4		0-60 sec	
TEXT	137	Operation_Z3	Forward		Zone Operation	
TEXT	138	OperationPP_Z3	OFF		OFF/ON	
NUM	139	X1PP_Z3	10,96		0.1-400 ohms	
NUM	140	R1PP_Z3	6,15		0.1-400 ohms	
NUM	141	RFPP_Z3	5		0.1-400 ohms	
TEXT	142	Timer t3PP	ON		OFF/ON	
NUM	143	t3PP	0,8		0-60 sec	
TEXT	144	OperationPE_Z3	ON		OFF/ON	
NUM	145	X1PE_Z3	10,96		0.1-400 ohms	
NUM	146	R1PE_Z3	6,15		0.1-400 ohms	
NUM	147	X0PE_Z3	63,93		0.1-1200 ohms	
NUM	148	R0PE_Z3	27,88		0.1-1200 ohms	
NUM	149	RFPE_Z3	15		0.1-400 ohms	
TEXT	150	Timer t3PE	ON		OFF/ON	
NUM	151	t3PE	0,8		0-60 sec	
TEXT	152	Operation_Z4	Reverse		Zone Operation	



Location | Device Remarks

Local Zone of Protection Data

Substation: Rurichu
LZOP ID: LINE 22
Name: 66kV Rurichu-Basochu feeder
LZOP Rank: 2

Change LZOP | View LZOP

Device Tag: 74 | Archived
Relay Tag: 72
Device Name: REL511_Baso Fdr(New)
Active Group:

<< Advanced

Group Displayed | Rename | Copy | Delete | Compare | Move

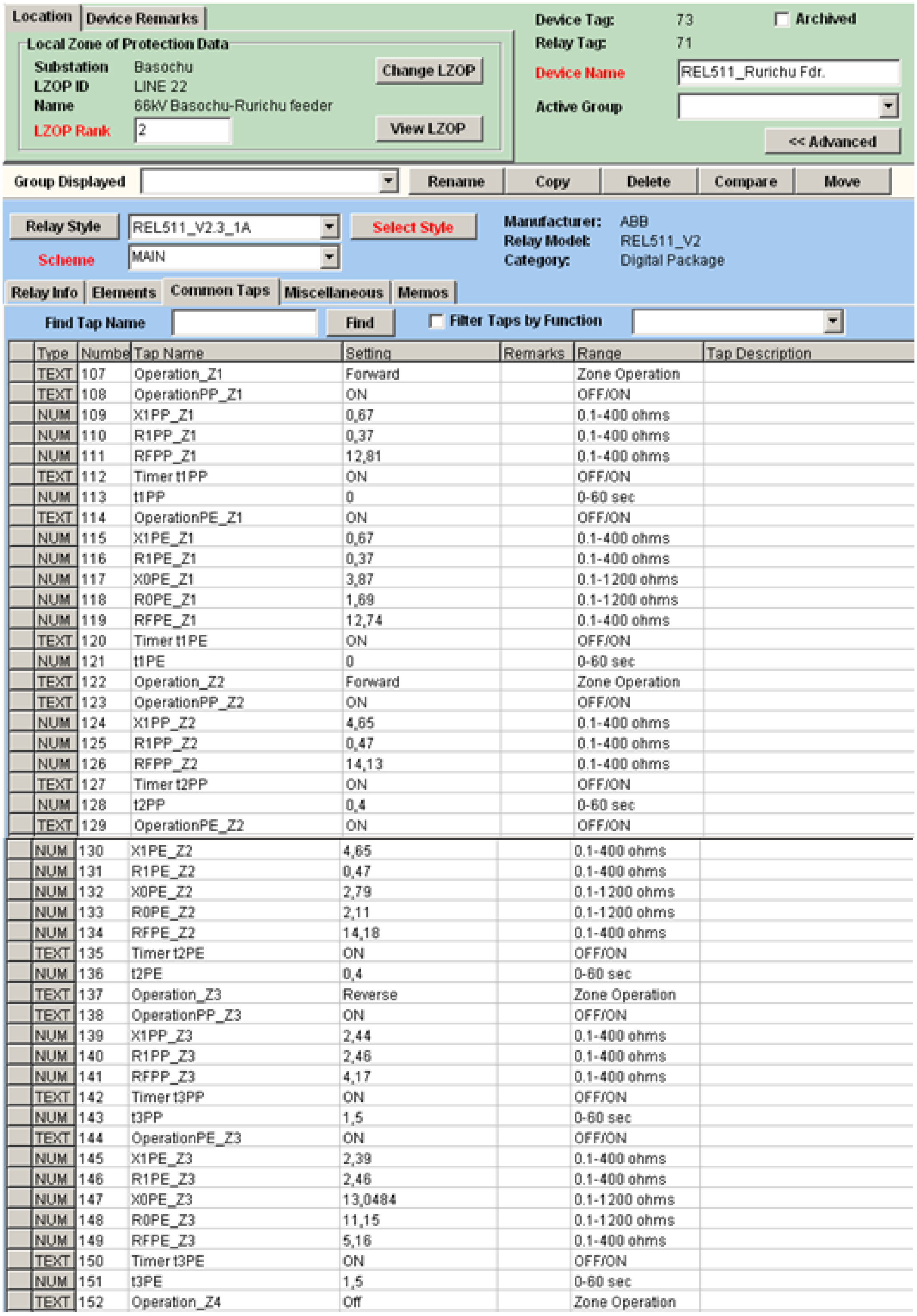
Relay Style: REL511_V2.3_1A | Select Style
Scheme: MAIN

Manufacturer: ABB
Relay Model: REL511_V2
Category: Digital Package

Relay Info | Elements | Common Taps | Miscellaneous | Memos

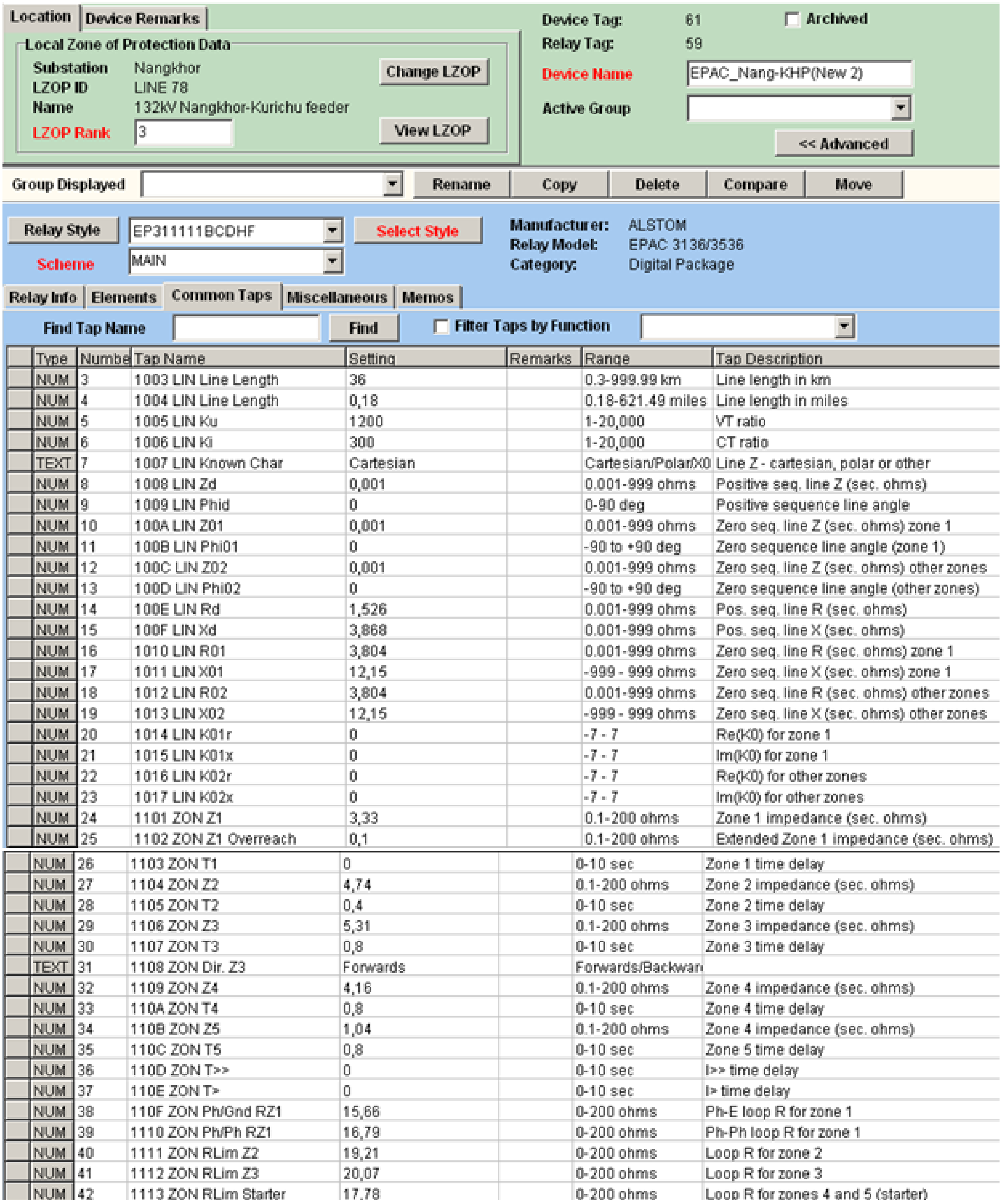
Find Tap Name | Find | Filter Taps by Function

Type	Numbe	Tap Name	Setting	Remarks	Range	Tap Description
TEXT	107	Operation_Z1	Forward		Zone Operation	
TEXT	108	OperationPP_Z1	ON		OFF/ON	
NUM	109	X1PP_Z1	0,67		0.1-400 ohms	
NUM	110	R1PP_Z1	0,37		0.1-400 ohms	
NUM	111	RFPP_Z1	6,01		0.1-400 ohms	
TEXT	112	Timer t1PP	ON		OFF/ON	
NUM	113	t1PP	0		0-60 sec	
TEXT	114	OperationPE_Z1	ON		OFF/ON	
NUM	115	X1PE_Z1	0,67		0.1-400 ohms	
NUM	116	R1PE_Z1	0,37		0.1-400 ohms	
NUM	117	X0PE_Z1	3,87		0.1-1200 ohms	
NUM	118	R0PE_Z1	1,69		0.1-1200 ohms	
NUM	119	RFPE_Z1	5,33		0.1-400 ohms	
TEXT	120	Timer t1PE	ON		OFF/ON	
NUM	121	t1PE	0		0-60 sec	
TEXT	122	Operation_Z2	Forward		Zone Operation	
TEXT	123	OperationPP_Z2	ON		OFF/ON	
NUM	124	X1PP_Z2	2,22		0.1-400 ohms	
NUM	125	R1PP_Z2	0,47		0.1-400 ohms	
NUM	126	RFPP_Z2	7,06		0.1-400 ohms	
TEXT	127	Timer t2PP	ON		OFF/ON	
NUM	128	t2PP	0,4		0-60 sec	
TEXT	129	OperationPE_Z2	ON		OFF/ON	
NUM	130	X1PE_Z2	2,22		0.1-400 ohms	
NUM	131	R1PE_Z2	0,47		0.1-400 ohms	
NUM	132	X0PE_Z2	1,332		0.1-1200 ohms	
NUM	133	R0PE_Z2	2,11		0.1-1200 ohms	
NUM	134	RFPE_Z2	7,82		0.1-400 ohms	
TEXT	135	Timer t2PE	ON		OFF/ON	
NUM	136	t2PE	0,4		0-60 sec	
TEXT	137	Operation_Z3	Reverse		Zone Operation	
TEXT	138	OperationPP_Z3	ON		OFF/ON	
NUM	139	X1PP_Z3	0,94		0.1-400 ohms	
NUM	140	R1PP_Z3	2,46		0.1-400 ohms	
NUM	141	RFPP_Z3	4,15		0.1-400 ohms	
TEXT	142	Timer t3PP	ON		OFF/ON	
NUM	143	t3PP	1,5		0-60 sec	
TEXT	144	OperationPE_Z3	ON		OFF/ON	
NUM	145	X1PE_Z3	0,99		0.1-400 ohms	
NUM	146	R1PE_Z3	2,46		0.1-400 ohms	
NUM	147	X0PE_Z3	5,40498		0.1-1200 ohms	
NUM	148	R0PE_Z3	11,15		0.1-1200 ohms	
NUM	149	RFPE_Z3	5,65		0.1-400 ohms	
TEXT	150	Timer t3PE	ON		OFF/ON	
NUM	151	t3PE	1,5		0-60 sec	
TEXT	152	Operation_Z4	Off		Zone Operation	



Type	Numbe	Tap Name	Setting	Remarks	Range	Tap Description
TEXT	107	Operation_Z1	Forward		Zone Operation	
TEXT	108	OperationPP_Z1	ON		OFF/ON	
NUM	109	X1PP_Z1	0,67		0.1-400 ohms	
NUM	110	R1PP_Z1	0,37		0.1-400 ohms	
NUM	111	RFPP_Z1	12,81		0.1-400 ohms	
TEXT	112	Timer t1PP	ON		OFF/ON	
NUM	113	t1PP	0		0-60 sec	
TEXT	114	OperationPE_Z1	ON		OFF/ON	
NUM	115	X1PE_Z1	0,67		0.1-400 ohms	
NUM	116	R1PE_Z1	0,37		0.1-400 ohms	
NUM	117	X0PE_Z1	3,87		0.1-1200 ohms	
NUM	118	R0PE_Z1	1,69		0.1-1200 ohms	
NUM	119	RFPE_Z1	12,74		0.1-400 ohms	
TEXT	120	Timer t1PE	ON		OFF/ON	
NUM	121	t1PE	0		0-60 sec	
TEXT	122	Operation_Z2	Forward		Zone Operation	
TEXT	123	OperationPP_Z2	ON		OFF/ON	
NUM	124	X1PP_Z2	4,65		0.1-400 ohms	
NUM	125	R1PP_Z2	0,47		0.1-400 ohms	
NUM	126	RFPP_Z2	14,13		0.1-400 ohms	
TEXT	127	Timer t2PP	ON		OFF/ON	
NUM	128	t2PP	0,4		0-60 sec	
TEXT	129	OperationPE_Z2	ON		OFF/ON	
NUM	130	X1PE_Z2	4,65		0.1-400 ohms	
NUM	131	R1PE_Z2	0,47		0.1-400 ohms	
NUM	132	X0PE_Z2	2,79		0.1-1200 ohms	
NUM	133	R0PE_Z2	2,11		0.1-1200 ohms	
NUM	134	RFPE_Z2	14,18		0.1-400 ohms	
TEXT	135	Timer t2PE	ON		OFF/ON	
NUM	136	t2PE	0,4		0-60 sec	
TEXT	137	Operation_Z3	Reverse		Zone Operation	
TEXT	138	OperationPP_Z3	ON		OFF/ON	
NUM	139	X1PP_Z3	2,44		0.1-400 ohms	
NUM	140	R1PP_Z3	2,46		0.1-400 ohms	
NUM	141	RFPP_Z3	4,17		0.1-400 ohms	
TEXT	142	Timer t3PP	ON		OFF/ON	
NUM	143	t3PP	1,5		0-60 sec	
TEXT	144	OperationPE_Z3	ON		OFF/ON	
NUM	145	X1PE_Z3	2,39		0.1-400 ohms	
NUM	146	R1PE_Z3	2,46		0.1-400 ohms	
NUM	147	X0PE_Z3	13,0484		0.1-1200 ohms	
NUM	148	R0PE_Z3	11,15		0.1-1200 ohms	
NUM	149	RFPE_Z3	5,16		0.1-400 ohms	
TEXT	150	Timer t3PE	ON		OFF/ON	
NUM	151	t3PE	1,5		0-60 sec	
TEXT	152	Operation_Z4	Off		Zone Operation	

132kV feeders:



Location | Device Remarks

Local Zone of Protection Data

Substation: Nangkhor
LZOP ID: LINE 78
Name: 132kV Nangkhor-Kurichu feeder
LZOP Rank: 3

Change LZOP | View LZOP

Device Tag: 61 | Archived
Relay Tag: 59
Device Name: EPAC_Nang-KHP(New 2)
Active Group:

<< Advanced

Group Displayed | Rename | Copy | Delete | Compare | Move

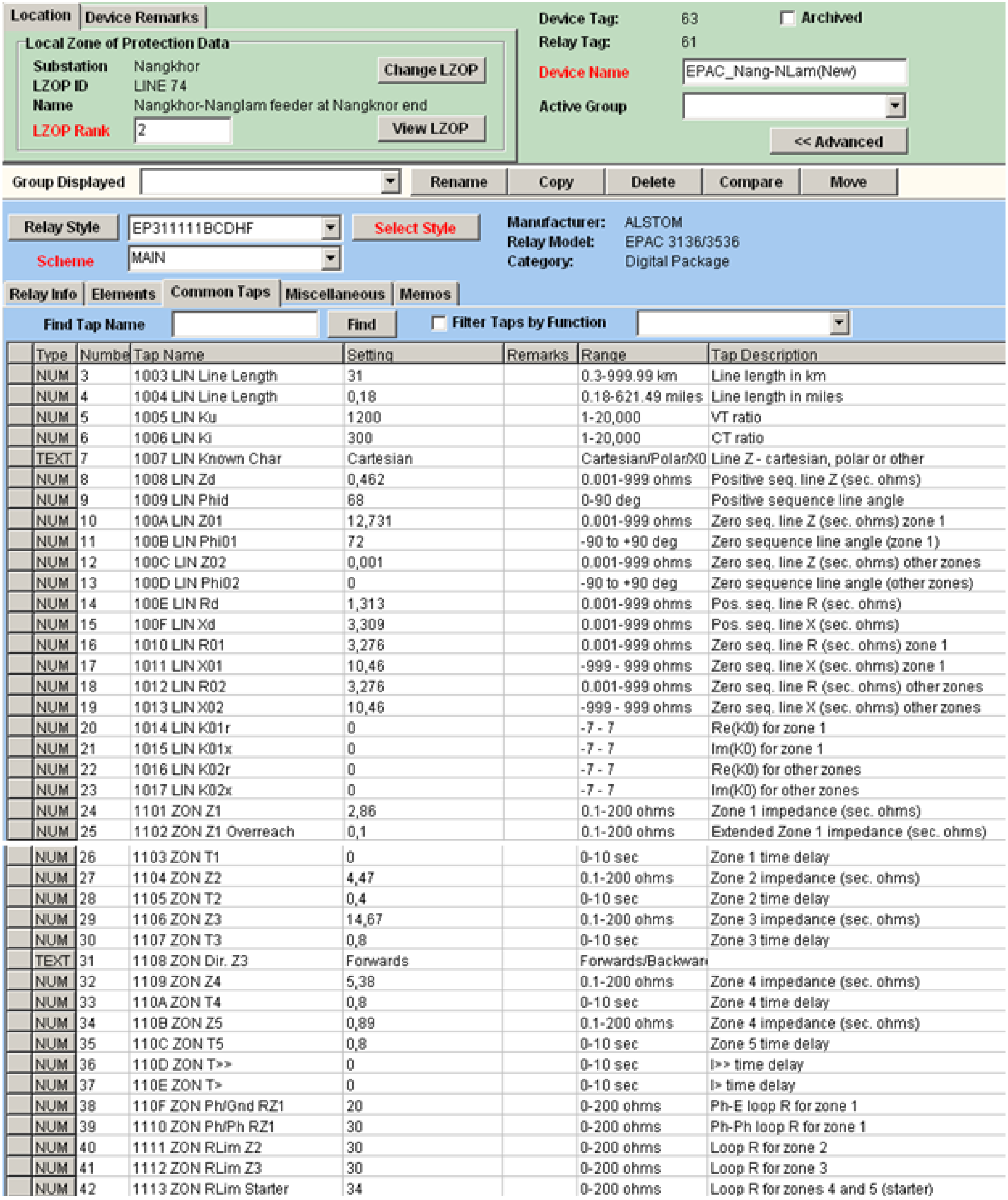
Relay Style: EP311111BCDHF | Select Style
Scheme: MAIN

Manufacturer: ALSTOM
Relay Model: EPAC 3136/3536
Category: Digital Package

Relay Info | Elements | Common Taps | Miscellaneous | Memos

Find Tap Name | Find | Filter Taps by Function

Type	Numbe	Tap Name	Setting	Remarks	Range	Tap Description
NUM	3	1003 LIN Line Length	36		0.3-999.99 km	Line length in km
NUM	4	1004 LIN Line Length	0,18		0.18-621.49 miles	Line length in miles
NUM	5	1005 LIN Ku	1200		1-20,000	VT ratio
NUM	6	1006 LIN Ki	300		1-20,000	CT ratio
TEXT	7	1007 LIN Known Char	Cartesian		Cartesian/Polar/X0	Line Z - cartesian, polar or other
NUM	8	1008 LIN Zd	0,001		0.001-999 ohms	Positive seq. line Z (sec. ohms)
NUM	9	1009 LIN Phid	0		0-90 deg	Positive sequence line angle
NUM	10	100A LIN Z01	0,001		0.001-999 ohms	Zero seq. line Z (sec. ohms) zone 1
NUM	11	100B LIN Phi01	0		-90 to +90 deg	Zero sequence line angle (zone 1)
NUM	12	100C LIN Z02	0,001		0.001-999 ohms	Zero seq. line Z (sec. ohms) other zones
NUM	13	100D LIN Phi02	0		-90 to +90 deg	Zero sequence line angle (other zones)
NUM	14	100E LIN Rd	1,526		0.001-999 ohms	Pos. seq. line R (sec. ohms)
NUM	15	100F LIN Xd	3,868		0.001-999 ohms	Pos. seq. line X (sec. ohms)
NUM	16	1010 LIN R01	3,804		0.001-999 ohms	Zero seq. line R (sec. ohms) zone 1
NUM	17	1011 LIN X01	12,15		-999 - 999 ohms	Zero seq. line X (sec. ohms) zone 1
NUM	18	1012 LIN R02	3,804		0.001-999 ohms	Zero seq. line R (sec. ohms) other zones
NUM	19	1013 LIN X02	12,15		-999 - 999 ohms	Zero seq. line X (sec. ohms) other zones
NUM	20	1014 LIN K01r	0		-7 - 7	Re(K0) for zone 1
NUM	21	1015 LIN K01x	0		-7 - 7	Im(K0) for zone 1
NUM	22	1016 LIN K02r	0		-7 - 7	Re(K0) for other zones
NUM	23	1017 LIN K02x	0		-7 - 7	Im(K0) for other zones
NUM	24	1101 ZON Z1	3,33		0.1-200 ohms	Zone 1 impedance (sec. ohms)
NUM	25	1102 ZON Z1 Overreach	0,1		0.1-200 ohms	Extended Zone 1 impedance (sec. ohms)
NUM	26	1103 ZON T1	0		0-10 sec	Zone 1 time delay
NUM	27	1104 ZON Z2	4,74		0.1-200 ohms	Zone 2 impedance (sec. ohms)
NUM	28	1105 ZON T2	0,4		0-10 sec	Zone 2 time delay
NUM	29	1106 ZON Z3	5,31		0.1-200 ohms	Zone 3 impedance (sec. ohms)
NUM	30	1107 ZON T3	0,8		0-10 sec	Zone 3 time delay
TEXT	31	1108 ZON Dir. Z3	Forwards		Forwards/Backward	
NUM	32	1109 ZON Z4	4,16		0.1-200 ohms	Zone 4 impedance (sec. ohms)
NUM	33	110A ZON T4	0,8		0-10 sec	Zone 4 time delay
NUM	34	110B ZON Z5	1,04		0.1-200 ohms	Zone 4 impedance (sec. ohms)
NUM	35	110C ZON T5	0,8		0-10 sec	Zone 5 time delay
NUM	36	110D ZON T>>	0		0-10 sec	I>> time delay
NUM	37	110E ZON T>	0		0-10 sec	I> time delay
NUM	38	110F ZON Ph/Gnd RZ1	15,66		0-200 ohms	Ph-E loop R for zone 1
NUM	39	1110 ZON Ph/Ph RZ1	16,79		0-200 ohms	Ph-Ph loop R for zone 1
NUM	40	1111 ZON RLim Z2	19,21		0-200 ohms	Loop R for zone 2
NUM	41	1112 ZON RLim Z3	20,07		0-200 ohms	Loop R for zone 3
NUM	42	1113 ZON RLim Starter	17,78		0-200 ohms	Loop R for zones 4 and 5 (starter)



Location | Device Remarks

Local Zone of Protection Data

Substation: Nangkhor
LZOP ID: LINE 74
Name: Nangkhor-Nanglam feeder at Nangknor end
LZOP Rank: 2

Change LZOP | View LZOP

Device Tag: 63 | Archived
Relay Tag: 61
Device Name: EPAC_Nang-NLam(New)
Active Group:

<< Advanced

Group Displayed: | Rename | Copy | Delete | Compare | Move

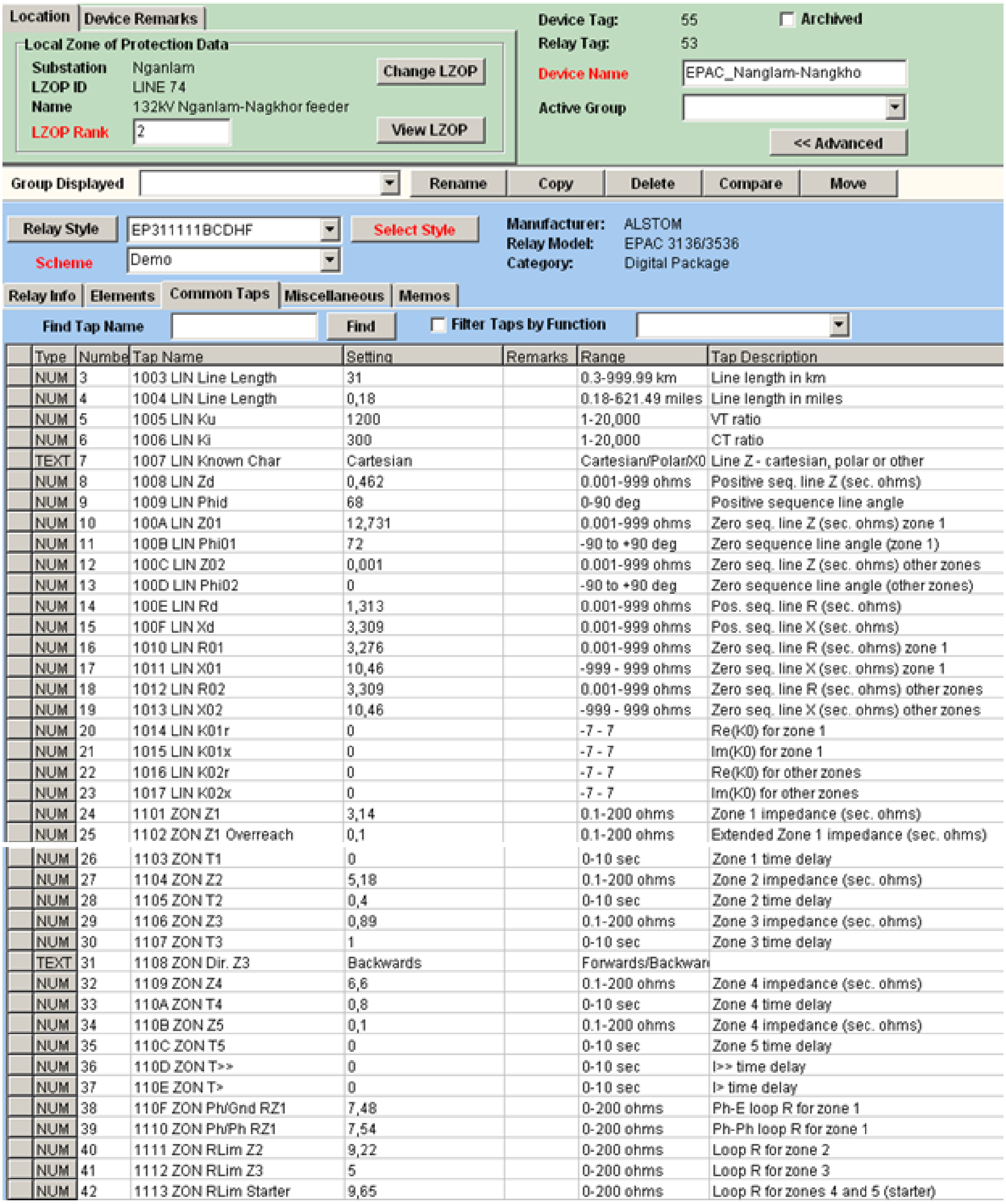
Relay Style: EP311111BCDHF | Select Style
Scheme: MAIN

Manufacturer: ALSTOM
Relay Model: EPAC 3136/3536
Category: Digital Package

Relay Info | Elements | Common Taps | Miscellaneous | Memos

Find Tap Name: | Find | Filter Taps by Function

Type	Numbe	Tap Name	Setting	Remarks	Range	Tap Description
NUM	3	1003 LIN Line Length	31		0.3-999.99 km	Line length in km
NUM	4	1004 LIN Line Length	0,18		0.18-621.49 miles	Line length in miles
NUM	5	1005 LIN Ku	1200		1-20,000	VT ratio
NUM	6	1006 LIN Ki	300		1-20,000	CT ratio
TEXT	7	1007 LIN Known Char	Cartesian		Cartesian/Polar/X0	Line Z - cartesian, polar or other
NUM	8	1008 LIN Zd	0,462		0.001-999 ohms	Positive seq. line Z (sec. ohms)
NUM	9	1009 LIN Phid	68		0-90 deg	Positive sequence line angle
NUM	10	100A LIN Z01	12,731		0.001-999 ohms	Zero seq. line Z (sec. ohms) zone 1
NUM	11	100B LIN Phi01	72		-90 to +90 deg	Zero sequence line angle (zone 1)
NUM	12	100C LIN Z02	0,001		0.001-999 ohms	Zero seq. line Z (sec. ohms) other zones
NUM	13	100D LIN Phi02	0		-90 to +90 deg	Zero sequence line angle (other zones)
NUM	14	100E LIN Rd	1,313		0.001-999 ohms	Pos. seq. line R (sec. ohms)
NUM	15	100F LIN Xd	3,309		0.001-999 ohms	Pos. seq. line X (sec. ohms)
NUM	16	1010 LIN R01	3,276		0.001-999 ohms	Zero seq. line R (sec. ohms) zone 1
NUM	17	1011 LIN X01	10,46		-999 - 999 ohms	Zero seq. line X (sec. ohms) zone 1
NUM	18	1012 LIN R02	3,276		0.001-999 ohms	Zero seq. line R (sec. ohms) other zones
NUM	19	1013 LIN X02	10,46		-999 - 999 ohms	Zero seq. line X (sec. ohms) other zones
NUM	20	1014 LIN K01r	0		-7 - 7	Re(K0) for zone 1
NUM	21	1015 LIN K01x	0		-7 - 7	Im(K0) for zone 1
NUM	22	1016 LIN K02r	0		-7 - 7	Re(K0) for other zones
NUM	23	1017 LIN K02x	0		-7 - 7	Im(K0) for other zones
NUM	24	1101 ZON Z1	2,86		0.1-200 ohms	Zone 1 impedance (sec. ohms)
NUM	25	1102 ZON Z1 Overreach	0,1		0.1-200 ohms	Extended Zone 1 impedance (sec. ohms)
NUM	26	1103 ZON T1	0		0-10 sec	Zone 1 time delay
NUM	27	1104 ZON Z2	4,47		0.1-200 ohms	Zone 2 impedance (sec. ohms)
NUM	28	1105 ZON T2	0,4		0-10 sec	Zone 2 time delay
NUM	29	1106 ZON Z3	14,67		0.1-200 ohms	Zone 3 impedance (sec. ohms)
NUM	30	1107 ZON T3	0,8		0-10 sec	Zone 3 time delay
TEXT	31	1108 ZON Dir. Z3	Forwards		Forwards/Backwar	
NUM	32	1109 ZON Z4	5,38		0.1-200 ohms	Zone 4 impedance (sec. ohms)
NUM	33	110A ZON T4	0,8		0-10 sec	Zone 4 time delay
NUM	34	110B ZON Z5	0,89		0.1-200 ohms	Zone 4 impedance (sec. ohms)
NUM	35	110C ZON T5	0,8		0-10 sec	Zone 5 time delay
NUM	36	110D ZON T>>	0		0-10 sec	I>> time delay
NUM	37	110E ZON T>	0		0-10 sec	I> time delay
NUM	38	110F ZON Ph/Gnd RZ1	20		0-200 ohms	Ph-E loop R for zone 1
NUM	39	1110 ZON Ph/Ph RZ1	30		0-200 ohms	Ph-Ph loop R for zone 1
NUM	40	1111 ZON RLim Z2	30		0-200 ohms	Loop R for zone 2
NUM	41	1112 ZON RLim Z3	30		0-200 ohms	Loop R for zone 3
NUM	42	1113 ZON RLim Starter	34		0-200 ohms	Loop R for zones 4 and 5 (starter)



Location | Device Remarks

Local Zone of Protection Data

Substation: Nganlam
LZOP ID: LINE 74
Name: 132kV Nganlam-Nagkhor feeder
LZOP Rank: 2

Change LZOP | View LZOP

Device Tag: 55 | Archived
Relay Tag: 53
Device Name: EPAC_Nanglam-Nangkho
Active Group:
<< Advanced

Group Displayed | Rename | Copy | Delete | Compare | Move

Relay Style: EP311111BCDHF | Select Style
Scheme: Demo

Manufacturer: ALSTOM
Relay Model: EPAC 3136/3536
Category: Digital Package

Relay Info | Elements | Common Taps | Miscellaneous | Memos

Find Tap Name | Find | Filter Taps by Function

Type	Numbe	Tap Name	Setting	Remarks	Range	Tap Description
NUM	3	1003 LIN Line Length	31		0.3-999.99 km	Line length in km
NUM	4	1004 LIN Line Length	0,18		0.18-621.49 miles	Line length in miles
NUM	5	1005 LIN Ku	1200		1-20,000	VT ratio
NUM	6	1006 LIN Ki	300		1-20,000	CT ratio
TEXT	7	1007 LIN Known Char	Cartesian		Cartesian/Polar/X0	Line Z - cartesian, polar or other
NUM	8	1008 LIN Zd	0,462		0.001-999 ohms	Positive seq. line Z (sec. ohms)
NUM	9	1009 LIN Phid	68		0-90 deg	Positive sequence line angle
NUM	10	100A LIN Z01	12,731		0.001-999 ohms	Zero seq. line Z (sec. ohms) zone 1
NUM	11	100B LIN Phi01	72		-90 to +90 deg	Zero sequence line angle (zone 1)
NUM	12	100C LIN Z02	0,001		0.001-999 ohms	Zero seq. line Z (sec. ohms) other zones
NUM	13	100D LIN Phi02	0		-90 to +90 deg	Zero sequence line angle (other zones)
NUM	14	100E LIN Rd	1,313		0.001-999 ohms	Pos. seq. line R (sec. ohms)
NUM	15	100F LIN Xd	3,309		0.001-999 ohms	Pos. seq. line X (sec. ohms)
NUM	16	1010 LIN R01	3,276		0.001-999 ohms	Zero seq. line R (sec. ohms) zone 1
NUM	17	1011 LIN X01	10,46		-999 - 999 ohms	Zero seq. line X (sec. ohms) zone 1
NUM	18	1012 LIN R02	3,309		0.001-999 ohms	Zero seq. line R (sec. ohms) other zones
NUM	19	1013 LIN X02	10,46		-999 - 999 ohms	Zero seq. line X (sec. ohms) other zones
NUM	20	1014 LIN K01r	0		-7 - 7	Re(K0) for zone 1
NUM	21	1015 LIN K01x	0		-7 - 7	Im(K0) for zone 1
NUM	22	1016 LIN K02r	0		-7 - 7	Re(K0) for other zones
NUM	23	1017 LIN K02x	0		-7 - 7	Im(K0) for other zones
NUM	24	1101 ZON Z1	3,14		0.1-200 ohms	Zone 1 impedance (sec. ohms)
NUM	25	1102 ZON Z1 Overreach	0,1		0.1-200 ohms	Extended Zone 1 impedance (sec. ohms)
NUM	26	1103 ZON T1	0		0-10 sec	Zone 1 time delay
NUM	27	1104 ZON Z2	5,18		0.1-200 ohms	Zone 2 impedance (sec. ohms)
NUM	28	1105 ZON T2	0,4		0-10 sec	Zone 2 time delay
NUM	29	1106 ZON Z3	0,89		0.1-200 ohms	Zone 3 impedance (sec. ohms)
NUM	30	1107 ZON T3	1		0-10 sec	Zone 3 time delay
TEXT	31	1108 ZON Dir. Z3	Backwards		Forwards/Backwar	
NUM	32	1109 ZON Z4	6,6		0.1-200 ohms	Zone 4 impedance (sec. ohms)
NUM	33	110A ZON T4	0,8		0-10 sec	Zone 4 time delay
NUM	34	110B ZON Z5	0,1		0.1-200 ohms	Zone 4 impedance (sec. ohms)
NUM	35	110C ZON T5	0		0-10 sec	Zone 5 time delay
NUM	36	110D ZON T>>	0		0-10 sec	I>> time delay
NUM	37	110E ZON T>	0		0-10 sec	I> time delay
NUM	38	110F ZON Ph/Gnd RZ1	7,48		0-200 ohms	Ph-E loop R for zone 1
NUM	39	1110 ZON Ph/Ph RZ1	7,54		0-200 ohms	Ph-Ph loop R for zone 1
NUM	40	1111 ZON RLim Z2	9,22		0-200 ohms	Loop R for zone 2
NUM	41	1112 ZON RLim Z3	5		0-200 ohms	Loop R for zone 3
NUM	42	1113 ZON RLim Starter	9,65		0-200 ohms	Loop R for zones 4 and 5 (starter)

Location | Device Remarks

Local Zone of Protection Data

Substation: Nganlam
LZOP ID: LINE 73
Name: 132 kV Nanglam-Tingtibi feeder
LZOP Rank: 2

Change LZOP | View LZOP

Device Tag: 57 | Archived
Relay Tag: 55
Device Name: EPAC_Nlam-Tinti(New)
Active Group:

<< Advanced

Group Displayed: | Rename | Copy | Delete | Compare | Move

Relay Style: EP311111BCDHF | Select Style
Scheme: MAIN

Manufacturer: ALSTOM
Relay Model: EPAC 3136/3536
Category: Digital Package

Relay Info | Elements | Common Taps | Miscellaneous | Memos

Find Tap Name | Find | Filter Taps by Function

Type	Numbe	Tap Name	Setting	Remarks	Range	Tap Description
NUM	3	1003 LIN Line Length	84,5		0.3-999.99 km	Line length in km
NUM	4	1004 LIN Line Length	0,18		0.18-621.49 miles	Line length in miles
NUM	5	1005 LIN Ku	1200		1-20,000	VT ratio
NUM	6	1006 LIN Ki	300		1-20,000	CT ratio
TEXT	7	1007 LIN Known Char	Cartesian		Cartesian/Polar/X0	Line Z - cartesian, polar or other
NUM	8	1008 LIN Zd	0,001		0.001-999 ohms	Positive seq. line Z (sec. ohms)
NUM	9	1009 LIN Phid	0		0-90 deg	Positive sequence line angle
NUM	10	100A LIN Z01	0,001		0.001-999 ohms	Zero seq. line Z (sec. ohms) zone 1
NUM	11	100B LIN Phi01	0		-90 to +90 deg	Zero sequence line angle (zone 1)
NUM	12	100C LIN Z02	0,001		0.001-999 ohms	Zero seq. line Z (sec. ohms) other zones
NUM	13	100D LIN Phi02	0		-90 to +90 deg	Zero sequence line angle (other zones)
NUM	14	100E LIN Rd	1,885		0.001-999 ohms	Pos. seq. line R (sec. ohms)
NUM	15	100F LIN Xd	4,781		0.001-999 ohms	Pos. seq. line X (sec. ohms)
NUM	16	1010 LIN R01	4,702		0.001-999 ohms	Zero seq. line R (sec. ohms) zone 1
NUM	17	1011 LIN X01	15,02		-999 - 999 ohms	Zero seq. line X (sec. ohms) zone 1
NUM	18	1012 LIN R02	4,702		0.001-999 ohms	Zero seq. line R (sec. ohms) other zones
NUM	19	1013 LIN X02	15,02		-999 - 999 ohms	Zero seq. line X (sec. ohms) other zones
NUM	20	1014 LIN K01r	0		-7 - 7	Re(K0) for zone 1
NUM	21	1015 LIN K01x	0		-7 - 7	Im(K0) for zone 1
NUM	22	1016 LIN K02r	0		-7 - 7	Re(K0) for other zones
NUM	23	1017 LIN K02x	0		-7 - 7	Im(K0) for other zones
NUM	24	1101 ZON Z1	7,81		0.1-200 ohms	Zone 1 impedance (sec. ohms)
NUM	25	1102 ZON Z1 Overreach	0,1		0.1-200 ohms	Extended Zone 1 impedance (sec. ohms)
NUM	26	1103 ZON T1	0		0-10 sec	Zone 1 time delay
NUM	27	1104 ZON Z2	12,2		0.1-200 ohms	Zone 2 impedance (sec. ohms)
NUM	28	1105 ZON T2	0,4		0-10 sec	Zone 2 time delay
NUM	29	1106 ZON Z3	2,44		0.1-200 ohms	Zone 3 impedance (sec. ohms)
NUM	30	1107 ZON T3	1		0-10 sec	Zone 3 time delay
TEXT	31	1108 ZON Dir. Z3	Backwards		Forwards/Backwar	
NUM	32	1109 ZON Z4	17,09		0.1-200 ohms	Zone 4 impedance (sec. ohms)
NUM	33	110A ZON T4	0,8		0-10 sec	Zone 4 time delay
NUM	34	110B ZON Z5	0,1		0.1-200 ohms	Zone 4 impedance (sec. ohms)
NUM	35	110C ZON T5	0		0-10 sec	Zone 5 time delay
NUM	36	110D ZON T>>	0		0-10 sec	I>> time delay
NUM	37	110E ZON T>	0		0-10 sec	I> time delay
NUM	38	110F ZON Ph/Gnd RZ1	4,62		0-200 ohms	Ph-E loop R for zone 1
NUM	39	1110 ZON Ph/Ph RZ1	4,62		0-200 ohms	Ph-Ph loop R for zone 1
NUM	40	1111 ZON RLim Z2	5		0-200 ohms	Loop R for zone 2
NUM	41	1112 ZON RLim Z3	5		0-200 ohms	Loop R for zone 3
NUM	42	1113 ZON RLim Starter	5		0-200 ohms	Loop R for zones 4 and 5 (starter)

Location | Device Remarks

Local Zone of Protection Data

Substation: Tintibi
LZOP ID: LINE 73
Name: 132 kV Tingtibi-Nanglam feeder
LZOP Rank: 2

Change LZOP | View LZOP

Device Tag: 58 | Archived
Relay Tag: 56
Device Name: EPAC_Ting-NLam(New)
Active Group:

<< Advanced

Group Displayed | Rename | Copy | Delete | Compare | Move

Relay Style: EP311111BCDHF | Select Style
Scheme: MAIN

Manufacturer: ALSTOM
Relay Model: EPAC 3136/3536
Category: Digital Package

Relay Info | Elements | Common Taps | Miscellaneous | Memos

Find Tap Name | Find | Filter Taps by Function

Type	Numbe	Tap Name	Setting	Remarks	Range	Tap Description
NUM	3	1003 LIN Line Length	84,5		0.3-999.99 km	Line length in km
NUM	4	1004 LIN Line Length	0,18		0.18-621.49 miles	Line length in miles
NUM	5	1005 LIN Ku	1200		1-20,000	VT ratio
NUM	6	1006 LIN Ki	300		1-20,000	CT ratio
TEXT	7	1007 LIN Known Char	Cartesian		Cartesian/Polar/X0	Line Z - cartesian, polar or other
NUM	8	1008 LIN Zd	0,001		0.001-999 ohms	Positive seq. line Z (sec. ohms)
NUM	9	1009 LIN Phid	0		0-90 deg	Positive sequence line angle
NUM	10	100A LIN Z01	0,001		0.001-999 ohms	Zero seq. line Z (sec. ohms) zone 1
NUM	11	100B LIN Phi01	0		-90 to +90 deg	Zero sequence line angle (zone 1)
NUM	12	100C LIN Z02	0,001		0.001-999 ohms	Zero seq. line Z (sec. ohms) other zones
NUM	13	100D LIN Phi02	0		-90 to +90 deg	Zero sequence line angle (other zones)
NUM	14	100E LIN Rd	1,885		0.001-999 ohms	Pos. seq. line R (sec. ohms)
NUM	15	100F LIN Xd	4,781		0.001-999 ohms	Pos. seq. line X (sec. ohms)
NUM	16	1010 LIN R01	4,702		0.001-999 ohms	Zero seq. line R (sec. ohms) zone 1
NUM	17	1011 LIN X01	15,02		-999 - 999 ohms	Zero seq. line X (sec. ohms) zone 1
NUM	18	1012 LIN R02	4,702		0.001-999 ohms	Zero seq. line R (sec. ohms) other zones
NUM	19	1013 LIN X02	15,02		-999 - 999 ohms	Zero seq. line X (sec. ohms) other zones
NUM	20	1014 LIN K01r	0		-7 - 7	Re(K0) for zone 1
NUM	21	1015 LIN K01x	0		-7 - 7	Im(K0) for zone 1
NUM	22	1016 LIN K02r	0		-7 - 7	Re(K0) for other zones
NUM	23	1017 LIN K02x	0		-7 - 7	Im(K0) for other zones
NUM	24	1101 ZON Z1	7,68		0.1-200 ohms	Zone 1 impedance (sec. ohms)
NUM	25	1102 ZON Z1 Overreach	0,1		0.1-200 ohms	Extended Zone 1 impedance (sec. ohms)
NUM	26	1103 ZON T1	0		0-10 sec	Zone 1 time delay
NUM	27	1104 ZON Z2	11,39		0.1-200 ohms	Zone 2 impedance (sec. ohms)
NUM	28	1105 ZON T2	0,4		0-10 sec	Zone 2 time delay
NUM	29	1106 ZON Z3	2,44		0.1-200 ohms	Zone 3 impedance (sec. ohms)
NUM	30	1107 ZON T3	1		0-10 sec	Zone 3 time delay
TEXT	31	1108 ZON Dir. Z3	Backwards		Forwards/Backwar	
NUM	32	1109 ZON Z4	13,44		0.1-200 ohms	Zone 4 impedance (sec. ohms)
NUM	33	110A ZON T4	0,8		0-10 sec	Zone 4 time delay
NUM	34	110B ZON Z5	0,1		0.1-200 ohms	Zone 4 impedance (sec. ohms)
NUM	35	110C ZON T5	0		0-10 sec	Zone 5 time delay
NUM	36	110D ZON T>>	0		0-10 sec	I>> time delay
NUM	37	110E ZON T>	0		0-10 sec	I> time delay
NUM	38	110F ZON Ph/Gnd RZ1	7,53		0-200 ohms	Ph-E loop R for zone 1
NUM	39	1110 ZON Ph/Ph RZ1	7,33		0-200 ohms	Ph-Ph loop R for zone 1
NUM	40	1111 ZON RLim Z2	8,36		0-200 ohms	Loop R for zone 2
NUM	41	1112 ZON RLim Z3	5		0-200 ohms	Loop R for zone 3
NUM	42	1113 ZON RLim Starter	8,34		0-200 ohms	Loop R for zones 4 and 5 (starter)

Location | Device Remarks

Local Zone of Protection Data

Substation: Tintibi
LZOP ID: LINE 72
Name: 132kV Tingtibi-Gelephu feeder
LZOP Rank: 2

Change LZOP | View LZOP

Device Tag: 59 | Archived
Relay Tag: 57
Device Name: EPAC_Tinti-Gel(New)
Active Group:

<< Advanced

Group Displayed: | Rename | Copy | Delete | Compare | Move

Relay Style: EP311111BCDHF | Select Style
Scheme: MAIN

Manufacturer: ALSTOM
Relay Model: EPAC 3136/3536
Category: Digital Package

Relay Info | Elements | Common Taps | Miscellaneous | Memos

Find Tap Name: | Find | Filter Taps by Function

Type	Numbe	Tap Name	Setting	Remarks	Range	Tap Description
NUM	3	1003 LIN Line Length	44,5		0.3-999.99 km	Line length in km
NUM	4	1004 LIN Line Length	0,18		0.18-621.49 miles	Line length in miles
NUM	5	1005 LIN Ku	1		1-20,000	VT ratio
NUM	6	1006 LIN Ki	1		1-20,000	CT ratio
TEXT	7	1007 LIN Known Char	Cartesian		Cartesian/Polar/X0	Line Z - cartesian, polar or other
NUM	8	1008 LIN Zd	0,001		0.001-999 ohms	Positive seq. line Z (sec. ohms)
NUM	9	1009 LIN Phid	0		0-90 deg	Positive sequence line angle
NUM	10	100A LIN Z01	0,001		0.001-999 ohms	Zero seq. line Z (sec. ohms) zone 1
NUM	11	100B LIN Phi01	0		-90 to +90 deg	Zero sequence line angle (zone 1)
NUM	12	100C LIN Z02	0,001		0.001-999 ohms	Zero seq. line Z (sec. ohms) other zones
NUM	13	100D LIN Phi02	0		-90 to +90 deg	Zero sequence line angle (other zones)
NUM	14	100E LIN Rd	1,886		0.001-999 ohms	Pos. seq. line R (sec. ohms)
NUM	15	100F LIN Xd	4,782		0.001-999 ohms	Pos. seq. line X (sec. ohms)
NUM	16	1010 LIN R01	4,703		0.001-999 ohms	Zero seq. line R (sec. ohms) zone 1
NUM	17	1011 LIN X01	15,02		-999 - 999 ohms	Zero seq. line X (sec. ohms) zone 1
NUM	18	1012 LIN R02	5,759		0.001-999 ohms	Zero seq. line R (sec. ohms) other zones
NUM	19	1013 LIN X02	18,39		-999 - 999 ohms	Zero seq. line X (sec. ohms) other zones
NUM	20	1014 LIN K01r	0		-7 - 7	Re(K0) for zone 1
NUM	21	1015 LIN K01x	0		-7 - 7	Im(K0) for zone 1
NUM	22	1016 LIN K02r	0		-7 - 7	Re(K0) for other zones
NUM	23	1017 LIN K02x	0		-7 - 7	Im(K0) for other zones
NUM	24	1101 ZON Z1	4,11		0.1-200 ohms	Zone 1 impedance (sec. ohms)
NUM	25	1102 ZON Z1 Overreach	0,1		0.1-200 ohms	Extended Zone 1 impedance (sec. ohms)
NUM	26	1103 ZON T1	0		0-10 sec	Zone 1 time delay
NUM	27	1104 ZON Z2	8,15		0.1-200 ohms	Zone 2 impedance (sec. ohms)
NUM	28	1105 ZON T2	0,4		0-10 sec	Zone 2 time delay
NUM	29	1106 ZON Z3	1,28		0.1-200 ohms	Zone 3 impedance (sec. ohms)
NUM	30	1107 ZON T3	1		0-10 sec	Zone 3 time delay
TEXT	31	1108 ZON Dir. Z3	Backwards		Forwards/Backward	
NUM	32	1109 ZON Z4	10,92		0.1-200 ohms	Zone 4 impedance (sec. ohms)
NUM	33	110A ZON T4	0,8		0-10 sec	Zone 4 time delay
NUM	34	110B ZON Z5	0,1		0.1-200 ohms	Zone 4 impedance (sec. ohms)
NUM	35	110C ZON T5	0		0-10 sec	Zone 5 time delay
NUM	36	110D ZON T>>	0		0-10 sec	I>> time delay
NUM	37	110E ZON T>	0		0-10 sec	I> time delay
NUM	38	110F ZON Ph/Gnd RZ1	4		0-200 ohms	Ph-E loop R for zone 1
NUM	39	1110 ZON Ph/Ph RZ1	4		0-200 ohms	Ph-Ph loop R for zone 1
NUM	40	1111 ZON RLim Z2	5		0-200 ohms	Loop R for zone 2
NUM	41	1112 ZON RLim Z3	5		0-200 ohms	Loop R for zone 3
NUM	42	1113 ZON RLim Starter	5		0-200 ohms	Loop R for zones 4 and 5 (starter)

Location | Device Remarks

Local Zone of Protection Data

Substation: Gelephu
LZOP ID: LINE 72
Name: 132kV Gelephu-Tingtibi feeder
LZOP Rank: 2

Change LZOP
View LZOP

Device Tag: 60
Archived
Relay Tag: 58
Device Name: EPAC_Gphu-Ting(New)
Active Group:
<< Advanced

Group Displayed:
Rename | Copy | Delete | Compare | Move

Relay Style: EP311111BCDHF
Select Style
Scheme: MAIN

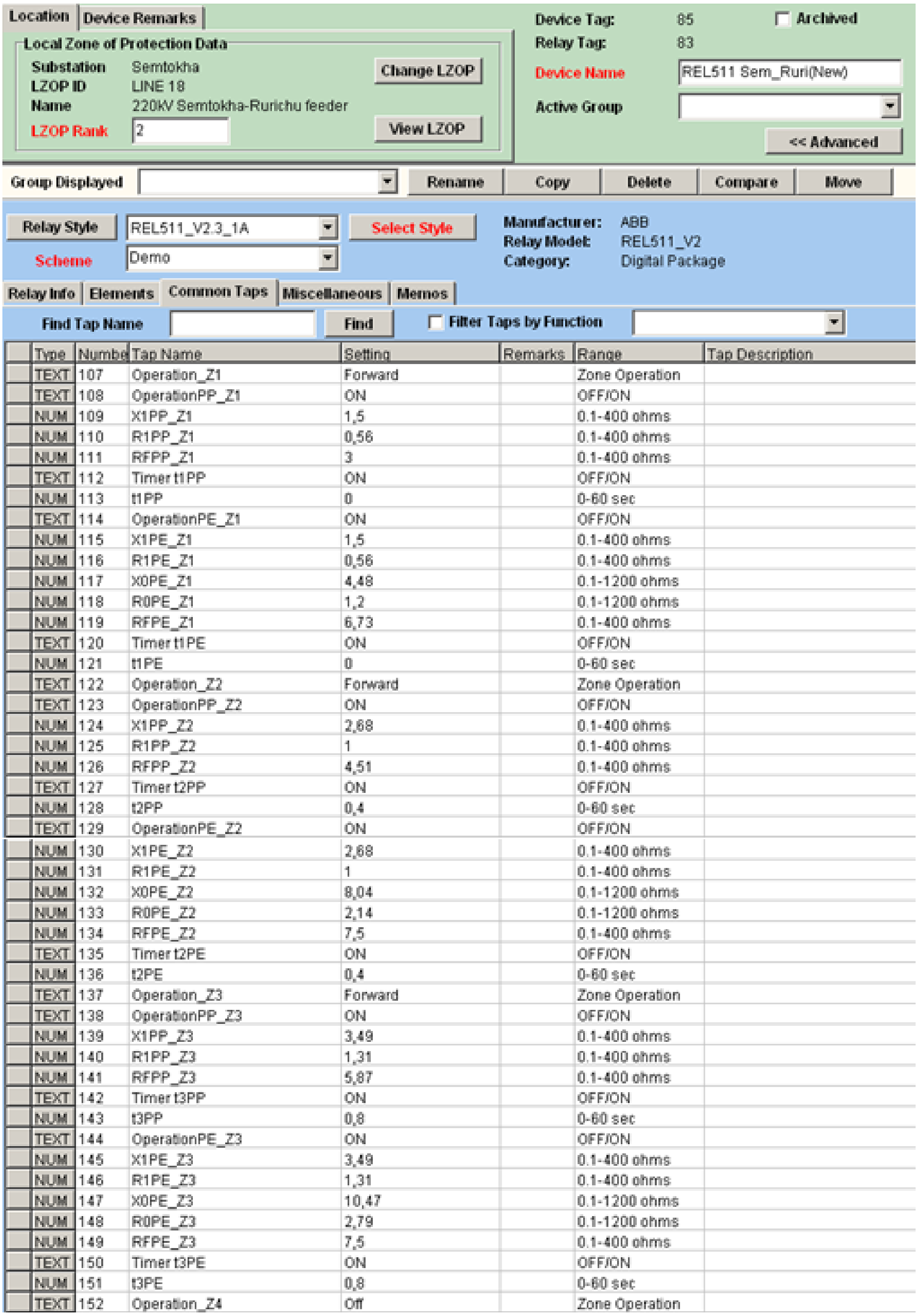
Manufacturer: ALSTOM
Relay Model: EPAC 3136/3536
Category: Digital Package

Relay Info | Elements | Common Taps | Miscellaneous | Memos

Find Tap Name: Find
Filter Taps by Function

Type	Numbe	Tap Name	Setting	Remarks	Range	Tap Description
NUM	3	1003 LIN Line Length	44,5		0.3-999.99 km	Line length in km
NUM	4	1004 LIN Line Length	0,18		0.18-621.49 miles	Line length in miles
NUM	5	1005 LIN Ku	1		1-20,000	VT ratio
NUM	6	1006 LIN Ki	1		1-20,000	CT ratio
TEXT	7	1007 LIN Known Char	Cartesian		Cartesian/Polar/X0	Line Z - cartesian, polar or other
NUM	8	1008 LIN Zd	0,001		0.001-999 ohms	Positive seq. line Z (sec. ohms)
NUM	9	1009 LIN Phid	0		0-90 deg	Positive sequence line angle
NUM	10	100A LIN Z01	0,001		0.001-999 ohms	Zero seq. line Z (sec. ohms) zone 1
NUM	11	100B LIN Phi01	0		-90 to +90 deg	Zero sequence line angle (zone 1)
NUM	12	100C LIN Z02	0,001		0.001-999 ohms	Zero seq. line Z (sec. ohms) other zones
NUM	13	100D LIN Phi02	0		-90 to +90 deg	Zero sequence line angle (other zones)
NUM	14	100E LIN Rd	1,886		0.001-999 ohms	Pos. seq. line R (sec. ohms)
NUM	15	100F LIN Xd	4,782		0.001-999 ohms	Pos. seq. line X (sec. ohms)
NUM	16	1010 LIN R01	4,703		0.001-999 ohms	Zero seq. line R (sec. ohms) zone 1
NUM	17	1011 LIN X01	15,02		-999 - 999 ohms	Zero seq. line X (sec. ohms) zone 1
NUM	18	1012 LIN R02	6,488		0.001-999 ohms	Zero seq. line R (sec. ohms) other zones
NUM	19	1013 LIN X02	20,72		-999 - 999 ohms	Zero seq. line X (sec. ohms) other zones
NUM	20	1014 LIN K01r	0		-7 - 7	Re(K0) for zone 1
NUM	21	1015 LIN K01x	0		-7 - 7	Im(K0) for zone 1
NUM	22	1016 LIN K02r	0		-7 - 7	Re(K0) for other zones
NUM	23	1017 LIN K02x	0		-7 - 7	Im(K0) for other zones
NUM	24	1101 ZON Z1	4,11		0.1-200 ohms	Zone 1 impedance (sec. ohms)
NUM	25	1102 ZON Z1 Overreach	0,1		0.1-200 ohms	Extended Zone 1 impedance (sec. ohms)
NUM	26	1103 ZON T1	0		0-10 sec	Zone 1 time delay
NUM	27	1104 ZON Z2	7,1		0.1-200 ohms	Zone 2 impedance (sec. ohms)
NUM	28	1105 ZON T2	0,4		0-10 sec	Zone 2 time delay
NUM	29	1106 ZON Z3	1,28		0.1-200 ohms	Zone 3 impedance (sec. ohms)
NUM	30	1107 ZON T3	1		0-10 sec	Zone 3 time delay
TEXT	31	1108 ZON Dir. Z3	Backwards		Forwards/Backwar	
NUM	32	1109 ZON Z4	12,95		0.1-200 ohms	Zone 4 impedance (sec. ohms)
NUM	33	110A ZON T4	0,8		0-10 sec	Zone 4 time delay
NUM	34	110B ZON Z5	0,1		0.1-200 ohms	Zone 4 impedance (sec. ohms)
NUM	35	110C ZON T5	0		0-10 sec	Zone 5 time delay
NUM	36	110D ZON T>>	0		0-10 sec	I>> time delay
NUM	37	110E ZON T>	0		0-10 sec	I> time delay
NUM	38	110F ZON Ph/Gnd RZ1	4		0-200 ohms	Ph-E loop R for zone 1
NUM	39	1110 ZON Ph/Ph RZ1	4		0-200 ohms	Ph-Ph loop R for zone 1
NUM	40	1111 ZON RLim Z2	5		0-200 ohms	Loop R for zone 2
NUM	41	1112 ZON RLim Z3	5		0-200 ohms	Loop R for zone 3
NUM	42	1113 ZON RLim Starter	5		0-200 ohms	Loop R for zones 4 and 5 (starter)

220kV Feeders:



Location | Device Remarks

Local Zone of Protection Data

Substation: Semtokha
LZOP ID: LINE 18
Name: 220kV Semtokha-Rurichu feeder
LZOP Rank: 2

Change LZOP | View LZOP

Device Tag: 85 | Archived
Relay Tag: 83
Device Name: REL511 Sem_Ruri(New)
Active Group:

<< Advanced

Group Displayed: | Rename | Copy | Delete | Compare | Move

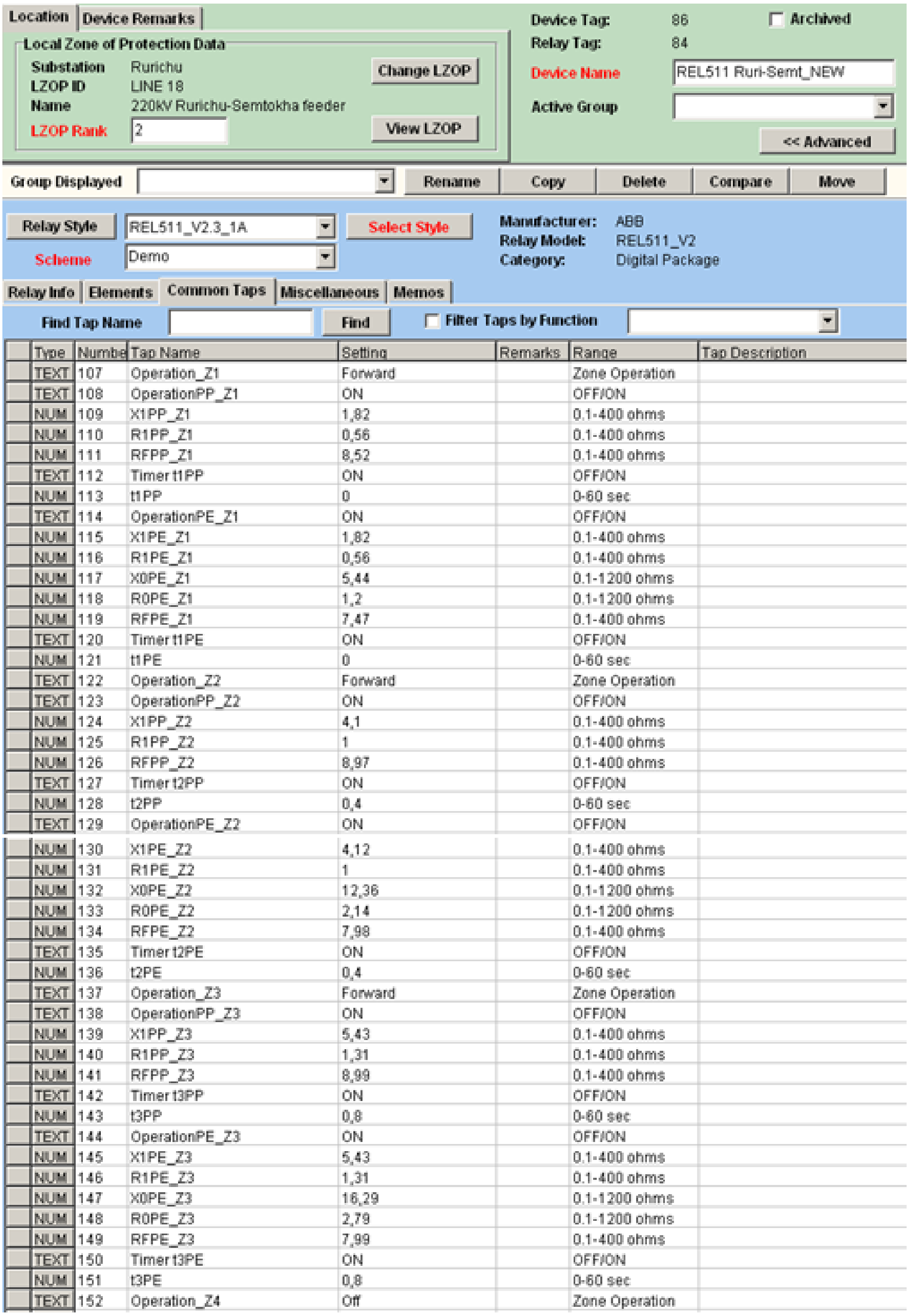
Relay Style: REL511_V2.3_1A | Select Style
Scheme: Demo

Manufacturer: ABB
Relay Model: REL511_V2
Category: Digital Package

Relay Info | Elements | Common Taps | Miscellaneous | Memos

Find Tap Name: | Find | Filter Taps by Function

Type	Numbe	Tap Name	Setting	Remarks	Range	Tap Description
TEXT	107	Operation_Z1	Forward		Zone Operation	
TEXT	108	OperationPP_Z1	ON		OFF/ON	
NUM	109	X1PP_Z1	1,5		0.1-400 ohms	
NUM	110	R1PP_Z1	0,56		0.1-400 ohms	
NUM	111	RFPP_Z1	3		0.1-400 ohms	
TEXT	112	Timer t1PP	ON		OFF/ON	
NUM	113	t1PP	0		0-60 sec	
TEXT	114	OperationPE_Z1	ON		OFF/ON	
NUM	115	X1PE_Z1	1,5		0.1-400 ohms	
NUM	116	R1PE_Z1	0,56		0.1-400 ohms	
NUM	117	X0PE_Z1	4,48		0.1-1200 ohms	
NUM	118	R0PE_Z1	1,2		0.1-1200 ohms	
NUM	119	RFPE_Z1	6,73		0.1-400 ohms	
TEXT	120	Timer t1PE	ON		OFF/ON	
NUM	121	t1PE	0		0-60 sec	
TEXT	122	Operation_Z2	Forward		Zone Operation	
TEXT	123	OperationPP_Z2	ON		OFF/ON	
NUM	124	X1PP_Z2	2,68		0.1-400 ohms	
NUM	125	R1PP_Z2	1		0.1-400 ohms	
NUM	126	RFPP_Z2	4,51		0.1-400 ohms	
TEXT	127	Timer t2PP	ON		OFF/ON	
NUM	128	t2PP	0,4		0-60 sec	
TEXT	129	OperationPE_Z2	ON		OFF/ON	
NUM	130	X1PE_Z2	2,68		0.1-400 ohms	
NUM	131	R1PE_Z2	1		0.1-400 ohms	
NUM	132	X0PE_Z2	8,04		0.1-1200 ohms	
NUM	133	R0PE_Z2	2,14		0.1-1200 ohms	
NUM	134	RFPE_Z2	7,5		0.1-400 ohms	
TEXT	135	Timer t2PE	ON		OFF/ON	
NUM	136	t2PE	0,4		0-60 sec	
TEXT	137	Operation_Z3	Forward		Zone Operation	
TEXT	138	OperationPP_Z3	ON		OFF/ON	
NUM	139	X1PP_Z3	3,49		0.1-400 ohms	
NUM	140	R1PP_Z3	1,31		0.1-400 ohms	
NUM	141	RFPP_Z3	5,87		0.1-400 ohms	
TEXT	142	Timer t3PP	ON		OFF/ON	
NUM	143	t3PP	0,8		0-60 sec	
TEXT	144	OperationPE_Z3	ON		OFF/ON	
NUM	145	X1PE_Z3	3,49		0.1-400 ohms	
NUM	146	R1PE_Z3	1,31		0.1-400 ohms	
NUM	147	X0PE_Z3	10,47		0.1-1200 ohms	
NUM	148	R0PE_Z3	2,79		0.1-1200 ohms	
NUM	149	RFPE_Z3	7,5		0.1-400 ohms	
TEXT	150	Timer t3PE	ON		OFF/ON	
NUM	151	t3PE	0,8		0-60 sec	
TEXT	152	Operation_Z4	Off		Zone Operation	



Location | Device Remarks

Local Zone of Protection Data

Substation: Rurichu

LZOP ID: LINE 18

Name: 220kV Rurichu-Semtokha feeder

LZOP Rank: 2

Change LZOP | View LZOP

Device Tag: 86 | Archived

Relay Tag: 84

Device Name: REL511 Ruri-Semt_NEW

Active Group

<< Advanced

Group Displayed | Rename | Copy | Delete | Compare | Move

Relay Style: REL511_V2.3_1A | Select Style

Scheme: Demo

Manufacturer: ABB

Relay Model: REL511_V2

Category: Digital Package

Relay Info | Elements | Common Taps | Miscellaneous | Memos

Find Tap Name | Find | Filter Taps by Function

Type	Numbe	Tap Name	Setting	Remarks	Range	Tap Description
TEXT	107	Operation_Z1	Forward		Zone Operation	
TEXT	108	OperationPP_Z1	ON		OFF/ON	
NUM	109	X1PP_Z1	1,82		0.1-400 ohms	
NUM	110	R1PP_Z1	0,56		0.1-400 ohms	
NUM	111	RFPP_Z1	8,52		0.1-400 ohms	
TEXT	112	Timer t1PP	ON		OFF/ON	
NUM	113	t1PP	0		0-60 sec	
TEXT	114	OperationPE_Z1	ON		OFF/ON	
NUM	115	X1PE_Z1	1,82		0.1-400 ohms	
NUM	116	R1PE_Z1	0,56		0.1-400 ohms	
NUM	117	X0PE_Z1	5,44		0.1-1200 ohms	
NUM	118	R0PE_Z1	1,2		0.1-1200 ohms	
NUM	119	RFPE_Z1	7,47		0.1-400 ohms	
TEXT	120	Timer t1PE	ON		OFF/ON	
NUM	121	t1PE	0		0-60 sec	
TEXT	122	Operation_Z2	Forward		Zone Operation	
TEXT	123	OperationPP_Z2	ON		OFF/ON	
NUM	124	X1PP_Z2	4,1		0.1-400 ohms	
NUM	125	R1PP_Z2	1		0.1-400 ohms	
NUM	126	RFPP_Z2	8,97		0.1-400 ohms	
TEXT	127	Timer t2PP	ON		OFF/ON	
NUM	128	t2PP	0,4		0-60 sec	
TEXT	129	OperationPE_Z2	ON		OFF/ON	
NUM	130	X1PE_Z2	4,12		0.1-400 ohms	
NUM	131	R1PE_Z2	1		0.1-400 ohms	
NUM	132	X0PE_Z2	12,36		0.1-1200 ohms	
NUM	133	R0PE_Z2	2,14		0.1-1200 ohms	
NUM	134	RFPE_Z2	7,98		0.1-400 ohms	
TEXT	135	Timer t2PE	ON		OFF/ON	
NUM	136	t2PE	0,4		0-60 sec	
TEXT	137	Operation_Z3	Forward		Zone Operation	
TEXT	138	OperationPP_Z3	ON		OFF/ON	
NUM	139	X1PP_Z3	5,43		0.1-400 ohms	
NUM	140	R1PP_Z3	1,31		0.1-400 ohms	
NUM	141	RFPP_Z3	8,99		0.1-400 ohms	
TEXT	142	Timer t3PP	ON		OFF/ON	
NUM	143	t3PP	0,8		0-60 sec	
TEXT	144	OperationPE_Z3	ON		OFF/ON	
NUM	145	X1PE_Z3	5,43		0.1-400 ohms	
NUM	146	R1PE_Z3	1,31		0.1-400 ohms	
NUM	147	X0PE_Z3	16,29		0.1-1200 ohms	
NUM	148	R0PE_Z3	2,79		0.1-1200 ohms	
NUM	149	RFPE_Z3	7,99		0.1-400 ohms	
TEXT	150	Timer t3PE	ON		OFF/ON	
NUM	151	t3PE	0,8		0-60 sec	
TEXT	152	Operation_Z4	Off		Zone Operation	

67N Relay setting details:

Substation: Kurichhu – R1

```
LZOP: "132kV Kurichu_Nangkhor feeder" (LINE)

67N_CDD21_New        Tag:    92
Model                 CDD 21
Style                 CDD21_1A_0.2-0.8
Branch Main CT: 45-42 Ckt 1 (132.0 kV) to 42 Bus_132Nang (Nangkhor)
CT Ratio:          500.00 YY
Pickup             0.20 R. Amps
Time Dial          0.22377
Characteristic   NORMAL INVERSE
Test Time          0.96 seconds
Test Current       500.00 percent
```

Substation: Nangkhor – R2

```
LZOP: "Nangkhor-Nanglam feeder at Nangknor end" (LINE)

67N_CDD21_NalamFdr.  Tag:    86
Model              CDD 21
Style              CDD21_1A_0.2-0.8
Branch Main CT: 42-41 Ckt 1 (132.0 kV) to 41 Bus_132Nglam (Nganlam)
CT Ratio:          300.00 YY
Pickup             0.20 R. Amps
Time Dial          0.19905
Characteristic   NORMAL INVERSE
Test Time          0.85 seconds
Test Current       500.00 percent
```

Substation: Nganlam – R3

```
LZOP: "132 kV Nanglam-Tingtibi feeder" (LINE)

67N_CDD21_TitibiFdr. Tag:    89
Model              CDD 21
Style              CDD21_1A_0.2-0.8
Branch Main CT: 41-40 Ckt 1 (132.0 kV) to 40 Bus_132Ting (Tintibi)
CT Ratio:          300.00 YY
Pickup             0.20 R. Amps
Time Dial          0.16398
Characteristic   NORMAL INVERSE
Test Time          0.70 seconds
Test Current       500.00 percent
```

Substation: Tintibi- R4

```
LZOP: "132kV Tingtibi-Gelephu feeder" (LINE)

67n_CDD21-Gele Fdr.  Tag:    94
Model              CDD 21
Style              CDD21_1A_0.2-0.8
Branch Main CT: 40-39 Ckt 1 (132.0 kV) to 39 Bus_132Gelp (Gelephu)
CT Ratio:          300.00 YY
Pickup             0.20 R. Amps
Time Dial          0.12900
Characteristic   NORMAL INVERSE
Test Time          0.55 seconds
Test Current       500.00 percent
```

Substation: Gelephu – R5

```
LZOP: "132kV Gelephu-Salakati feeder" (LINE)

67N_CDD21_New         Tag:    93
Model               CDD 21
Style               CDD21_1A_0.2-0.8
Branch Main CT: 39-37 Ckt 1 (132.0 kV) to 37 Bus_132Salak (Salakati)
CT Ratio:           300.00 YY
Pickup              0.20 R. Amps
Time Dial           0.10001
Characteristic  NORMAL INVERSE
Test Time           0.43 seconds
Test Current        500.00 percent
```

Substation: Nangkhor – R1

```
LZOP: "132kV Nangkhor-Kurichu feeder" (LINE)

CDD21_EF(New)         Tag:    96
Model               CDD 21
Style               CDD21_1A_0.2-0.8
Branch Main CT: 42-45 Ckt 1 (132.0 kV) to 45 Bus_132KHP (Kurichhu)
CT Ratio:           300.00 YY
Pickup              0.20 R. Amps
Time Dial           0.15600
Characteristic  NORMAL INVERSE
Test Time           0.67 seconds
Test Current        500.00 percent
```

Substation: Nganlam – R2

```
LZOP: "132kV Nganlam-Nagkhor feeder" (LINE)

67N_CDD21_Nang(New)   Tag:    97
Model               CDD 21
Style               CDD21_1A_0.2-0.8
Branch Main CT: 41-42 Ckt 1 (132.0 kV) to 42 Bus_132Nang (Nangkhor)
CT Ratio:           300.00 YY
Pickup              0.20 R. Amps
Time Dial           0.13592
Characteristic      NORMAL INVERSE
Test Time           0.58 seconds
Test Current        500.00 percent
```

Substation: Tintibi – R3

```
LZOP: "132 kV Tingtibi-Nanglam feeder" (LINE)

67N_CDD21_NLam(New)   Tag:    98
Model               CDD 21
Style               CDD21_1A_0.2-0.8
Branch Main CT: 40-41 Ckt 1 (132.0 kV) to 41 Bus_132Nglam (Nganlam)
CT Ratio:           300.00 YY
Pickup              0.20 R. Amps
Time Dial           0.11734
Characteristic      NORMAL INVERSE
Test Time           0.50 seconds
Test Current        500.00 percent
```

Substation: Gelephu – R4

```
LZOP: "132kV Gelephu-Tingtibi feeder" (LINE)

67N_CDD21-Tibi(New)  Tag:     99
Model                CDD 21
Style                CDD21_1A_0.2-0.8
Branch Main CT: 39-40 Ckt 1 (132.0 kV) to 40 Bus_132Ting (Tintibi)
CT Ratio:            300.00 YY
Pickup               0.20 R. Amps
Time Dial            0.10000
Characteristic       NORMAL INVERSE
Test Time            0.43 seconds
Test Current         500.00 percent
```

220kV feeders:

Substation: Semtokha

```
LZOP: "220kV Semtokha-Rurichu feeder" (LINE)

REL511 Sem_Ruri(New) Tag:     83
Model               REL511_V2
Style               REL511_V2.3_1A
1. Time OC IN>_TEF
Branch Main CT: 4-13 Ckt 1 (220.0 kV) to 13 Bus_220Ruri (Rurichu)
CT Ratio:    300.00 YY
Pickup               0.20 R. Amps
Time Dial      0.10000
Characteristic    STD INVERSE (IEC-A)
Test Time            0.43 seconds
Test Current     500.00 percent

4. Inst. OC IN1>
Branch Main CT: 4-13 Ckt 1 (220.0 kV) to 13 Bus_220Ruri (Rurichu)
CT Ratio:    300.00 YY
Pickup               4.46 R. Amps
Total Oper. Time          0.02 seconds
```

Substation: Chukha

```
LZOP: "220kV Chukha-Semtokha feeder" (LINE)

REL 511 Chukha-Semto Tag:     11
Model               REL511_V2
Style               REL511_V2.3_1A
2. Time OC IN>_TEF
Branch Main CT: 2-4 Ckt 1 (220.0 kV) to 4 Bus_220Semto (Semtokha)
CT Ratio:    600.00 YY
Pickup               0.15 R. Amps
Time Dial      0.11000
Characteristic    STD INVERSE (IEC-A)
Test Time            0.47 seconds
Test Current     500.00 percent

5. Inst. OC IN1>
Branch Main CT: 2-4 Ckt 1 (220.0 kV) to 4 Bus_220Semto (Semtokha)
CT Ratio:    600.00 YY
Pickup               3.87 R. Amps
Total Oper. Time          0.02 second
```

Substation: Malbesa

```
LZOP: "Malbesa to Chukha(220kV)" (LINE)

 MC R 1                Tag:     2
 Model            REL511_V2
 Style            REL511_V2.3_1A
 3. Time OC IN>_TEF
 Branch Main CT: 20-2 Ckt 1 (220.0 kV) to 2 Bus_220CHP (Chukha)
 CT Ratio:   800.00 YY
 Pickup            0.15 R. Amps
 Time Dial      0.12000
 Characteristic  STD INVERSE (IEC-A)
 Test Time        17.21 seconds
 Test Current   105.00 percent

 6. Inst. OC IN1>
 Branch Main CT: 20-2 Ckt 1 (220.0 kV) to 2 Bus_220CHP (Chukha)
 CT Ratio:   800.00 YY
 Pickup            3.95 R. Amps
 Total Oper. Time       0.02 seconds
```